REPORT RESUMES

ED 014 302 JC 670 915

ELECTRONIC TECHNOLOGY, A SUGGESTED TWO-YEAR POST-HIGH-SCHOOL PROGRAM. SIX-QUARTER PROGRAM.

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ILLINOIS UNIV., URBANA

REPORT NUMBER ENG-TECHNOL-SER-3 PUB DATE JUN 67

ILLINOIS STATE BOARD OF VOC. EDUC. AND REHABIL.

EDRS PRICE MF-$0.50 HC-$3.88 95P.

DESCRIPTORS- *JUNIOR COLLEGES, *ELECTROMECHANICAL TECHNOLOGY, SUBPROFESSIONALS, *VOCATIONAL EDUCATION, *TECHNICAL EDUCATION, ELECTRONICS, *ENGINEERING TECHNICIANS, PROGRAM PLANNING, COURSE CONTENT, COURSE DESCRIPTIONS,

THIS REPORT OUTLINES A 2-YEAR ELECTRONIC TECHNOLOGY PROGRAM ADJUSTED FROM A 4-SEMESTER TO A 6-QUARTER SEQUENCE. IT DESCRIBES THE PHILOSOPHY AND OBJECTIVES OF THE COURSE AND THE DESIRABLE CHARACTERISTICS OF THE FACULTY AND STUDENTS. IT GIVES THE CURRICULUM AND DETAILED COURSE OUTLINES FOR ALL PHASES OF THE PROGRAM AND FOR THE SUPPORTIVE STUDIES SUCH AS MATHEMATICS, PHYSICS, DRAFTING, ENGLISH (INCLUDING REPORT WRITING), PSYCHOLOGY AND HUMAN RELATIONS, INDUSTRIAL ORGANIZATION, ECONOMICS, AND AMERICAN HISTORY AND GOVERNMENT. THE REPORT INCLUDES SUGGESTIONS FOR THE LABORATORY, ITS EQUIPMENT AND REFERENCE MATERIALS, PROBABLE COSTS, AND SEVERAL WORKABLE FLOOR PLANS. (HH)

ED014302

ELECTRONIC TECHNOLOGY

Six-Quarter Program

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
OFFICE OF EDUCATION

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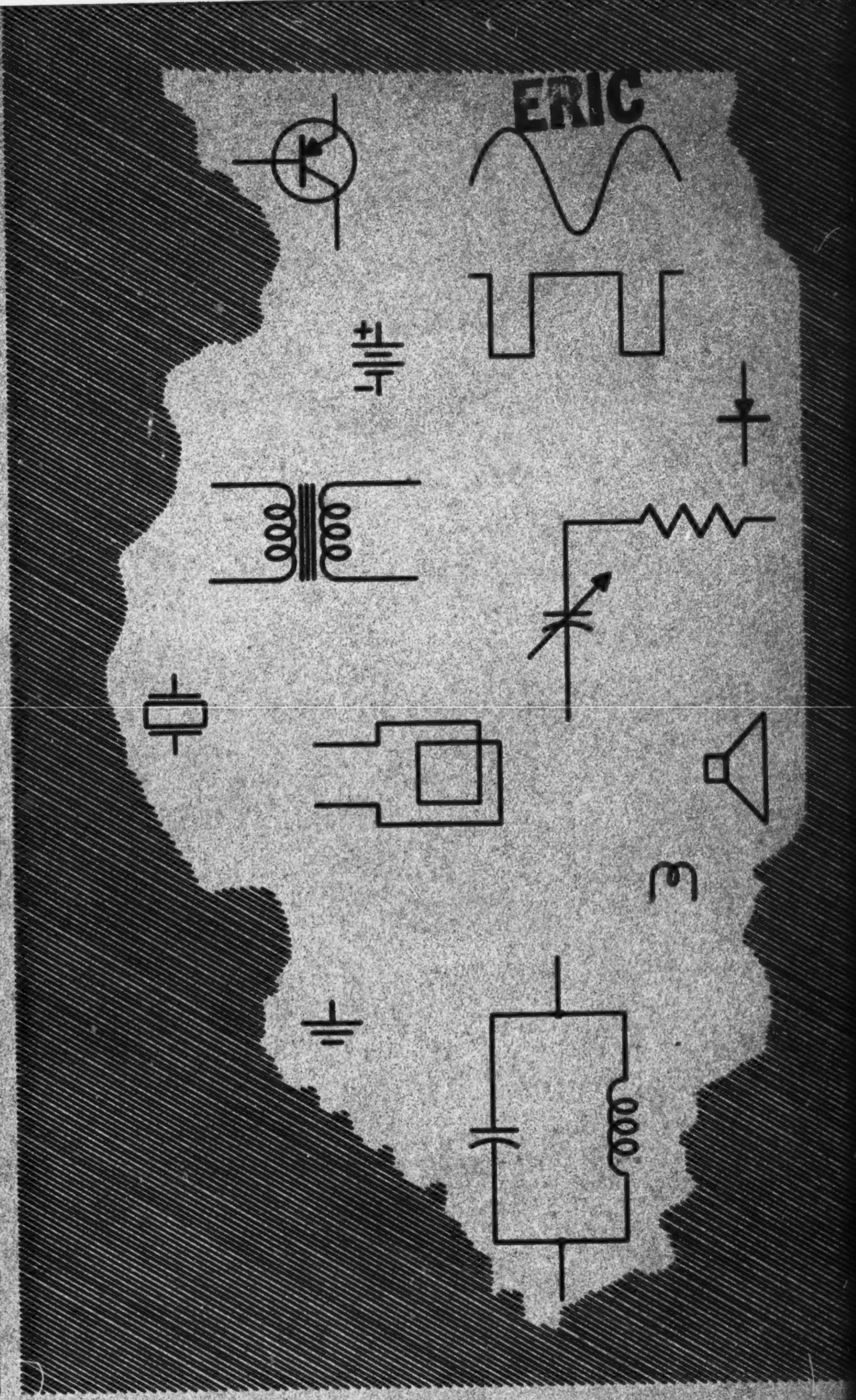
A Suggested Two-Year
Post-High-School Program



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ENGINEERING TECHNOLOGY SERIES
No. 3

A Curriculum Project Sponsored Jointly by the
ILLINOIS BOARD OF VOCATIONAL EDUCATION and the UNIVERSITY OF ILLINOIS

1967

JC 670915

ELECTRONIC TECHNOLOGY

A SUGGESTED TWO-YEAR POST-HIGH-SCHOOL PROGRAM
Six-Quarter Program

Developed by the Engineering Technology Curriculum Advisory Committee
of the College of Engineering, University of Illinois, Urbana

Engineering Technology Series
No. 3

A CURRICULUM PROJECT Sponsored Jointly by the

Illinois Board of Vocational Education, Springfield
Honorable Ray Page, State Superintendent of Public Instruction

and the University of Illinois, Urbana

June, 1967

Under terms of Vocational Education Act 1963

FOREWORD

In recent years a great deal of attention has been focused upon the educational programs to prepare engineering technicians. In the State of Illinois these programs were first implemented through funds available under Title VIII of the National Defense Education Act of 1958. Since 1959 the Engineering Technology Curriculum Advisory Committee of the College of Engineering at the University of Illinois has been working closely with the Technical Education Service of the Illinois Board of Vocational Education to help structure sound programs in engineering related technical education.

The enactment of the Junior College Act of 1965 has accelerated the growth of post-high school technical education programs. During the past eight years various conferences have been held to develop a spirit of cooperation between all of the groups involved with the development of technical education programs. The Vocational Education Act of 1963 has provided further stimulus for technical education.

To help identify the areas of study that would be normally followed in programs of engineering technology, a series of curriculum guides have been prepared for use by schools offering such programs. In 1963 a four-semester curriculum guide for Machine Design Technology was published as No. 1 in the Engineering Technology Series. This was revised and reprinted in 1965. In 1964 a four-semester curriculum guide for Electronic Technology was published as No. 2 in the Engineering Technology Series.

This publication is No. 3 of this Series and is a six-quarter curriculum guide in Electronic Technology. The need for this guide has been brought about by the large number of schools that are using the quarter system. The topical outlines have been completely reworked to provide meaningful sequencing of courses and topics. The participants of the 1964-65 and 1966-67 Academic Year Institutes for electronic teachers sponsored by the National Science Foundation held at the University of Illinois made significant contributions in developing this publication.

The funds for the project have been furnished by the Illinois Board of Vocational Education and the University of Illinois as a joint sponsored project under the terms of the Vocational Education Act of 1963. This bulletin is to serve as a guide to instructors and administrators developing six-quarter programs in Electronic Technology.

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PREFACE

This six-quarter program agrees, in principle, with the four-semester program that was previously published and identified as No. 2 of the Engineering Technology Series. The six-quarter program, however, provides greater degrees of freedom and flexibility than the four-semester program. The unique features of this particular curriculum are outlined on later pages of the front matter.

The development of a two-year electronic technology curriculum for either the six-quarter or the four-semester program, imposes some very real and difficult problems in the organization of courses and topics. The topics and courses in mathematics, circuits, and electronics are particularly challenging.

The objectives of an electronic technology curriculum demands a quantitative (as well as qualitative) analysis of circuits. Consequently, a good working knowledge of mathematics through calculus is a definite requirement in such a program. In addition, a knowledge of selected topics in differential equations and LaPlace transforms are highly desirable.

The topics for circuit analysis studies can be sequentially arranged into courses identified as resistive circuits, single-time-constant circuits, and linear network analysis (including transcient analysis). Correspondingly, electronics courses and topics can have a logical sequence of resistive electronic circuits, pulse circuits, linear electronic circuits, and nonlinear electronic circuits (such as oscillators). These groupings and titles for the circuits and electronics courses are receiving more and more attention in textbooks. An electronic technology curriculum demands a concentrated and continuing effort in the reorganization of mathematics, circuits and electronics topics.

The sequencing of topics in the mathematics, circuits and electronics courses of this electronic technology curriculum are developed in accordance with requirements of such a program without concern as to the availability of textbooks. Consequently, it may be necessary to support a selected text with supplementary material in support of the textbook. Some assistance for the development of supplementary material is provided in this publication by giving rather detailed course outlines for the circuits and electronics courses.

It is hopeful that the required textbooks will become available in the near future. In the meantime, the problem can also be resolved by not restricting every course to studies from a single textbook.

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ACKNOWLEDGMENTS

The project director wishes to acknowledge the contributions to the success of this project by various administrators and teachers of on going programs of engineering technology. In particular, the following persons have been most helpful:

John A Beaumont, Director, Vocational and Technical Division, Illinois Board of Vocational Education, Springfield, Illinois

Walter J. Bartz, Chief of Technical Occupations, Vocational and Technical Division, Illinois Board of Vocational Education, Springfield, Illinois

V. E. Burgener, Director of Research Coordinating Unit, Vocational and Technical Division, Illinois Board of Vocational Education, Springfield, Illinois

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The participants from the 1964-65 and 1966-67 Academic Year Institutes for Electronic teachers sponsored by the National Science Foundation who were actively involved in the preparation of some of the detailed outlines under the direction of Professor D. S. Babb are listed below:

Roger D. Bradley
Robert K. Christianson
John W. Cocroft
Ronald A. Colman
Gideon D. Frenkel
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Cyrus Kirshner
Tian S. Lim
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Roger A. Mussell
David A. Peterson
Frank G. Prew
Wayne L. Sabatke
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Jerry A. Sorensen
Marlow L. Sperstad
Otto J. Stoklosa
Vernal L. Taylor
Robert T. Wilson
Donaldson G. Woods

Philosophy Of Engineering Technology Education

General Requirements

The education program described in this publication is organized to provide 2 years of full-time study in the specific field of electronic technology. The course work outlined in this publication is so arranged as to provide a competency upon completion enabling the graduate to work directly with the design, test, development, and research groups of an industrial complex.

The increasing demands of our technocracy upon our technical personnel are such that additional academic training beyond the high school is a prerequisite for successful employment placement of our youth. Job obsolescence, due to new advances in our modern technology, require employees to obtain additional training to remain employable. The abilities required by our technical personnel have been broadly defined as follows:[1]

1. Facility with mathematics; ability to use algebra and trigonometry as tools in the development of ideas that make use of scientific and engineering principles; an understanding of, though not necessarily facility with, higher mathematics through analytical geometry, calculus, and differential equations, according to the requirements of the technology.
2. Proficiency in the application of physical science principles, including the basic concepts and laws of physics and chemistry that are pertinent to the individual's field of technology.
3. An understanding of the materials and processes commonly used in the technology.
4. An extensive knowledge of a field of specialization, with an understanding of the engineering and scientific activities that distinguish the technology of the field. The degree of competency and the depth of understanding should be sufficient to enable the individual to do such work as detail design procedures.
5. Communication skills that include the ability to interpret, analyze, and transmit facts and ideas graphically, orally, and in writing.

To further identify the educational criteria for programs of engineering technology, the American Society for Engineering Education has completed a study under a grant from the National Science Foundation on the evaluation of technical institute education. The results of this study have been published in a report entitled, Characteristic of Excellence in Engineering Technology Education.

The objectives, standards of excellence, and minimum subject area requirements as represented in the above two reports have been accepted generally by educators in the field of engineering technology. The structure and implementation of engineering technology curricula require a consideration of a number of factors, some of which are common to all engineering technology curriculum and others that are unique for the electronic technology curriculum to which this publication is directed.

Program Objectives

In general, the functions performed by the engineering technician are closely related to research, development and engineering activities. Accordingly, any engineering technology curriculum is constructed to provide the educational background necessary for the many functions of the technologist at the levels of design, development, testing, production and research.

The Curriculum

An engineering technology curriculum is a minimum two-year program of four semesters or six quarters leading to an Associate Degree. It is a college level program but differs significantly from a pre-engineering curriculum. The first two years of an engineering curriculum are primarily devoted to mathematics, science and general education, with very few specialized technical courses. On the other hand, an engineering technology program must initiate specialized technical courses early in the program if the desired objectives are to be accomplished within the time available. The sequencing of courses and topics must be carefully organized to permit the student to develop to the desired levels of competence. An engineering technology curriculum must conserve the rigor of effort on the part of the student that is equivalent to the rigor of effort required in a college program.

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[1] Division of Vocational Education, U. S. Office of Education, Occupational Criteria and Preparatory Curriculum Patterns in Technical Education Programs. Washington: U. S. Government Printing Office, 1962 (OE-80015) p. 5.

An engineering technology curriculum must be structured so that it prepares its graduates functionally:

1) To enter into a job and be immediately productive with a minimum of on-the-job training.
2) To provide the technical and scientific background to prepare him to keep abreast of developments in technology throughout his career.
3) To enable the graduate with a reasonable amount of industrial experience to advance into positions of increased responsibility.

In addition, it must also include sufficient work in the non-technical area to prepare the individual to participate fully in the society of which he is a part.

Faculty

The ultimate quality of the curriculum depends largely upon the quality of the faculty. The specialized nature of the curriculum requires that the teachers have special competencies. These competencies are based on technical proficiency in subject matter and industrial experience. Another important consideration is that all members of the engineering technology faculty understand the educational philosophy of such programs and be in harmony with the goals and unique organizational requirements that characterize this area of education.

To achieve the objectives of the curriculum, the subject matter cannot be taught as a series of independent courses, but must be presented as a closely integrated combination and sequence of educational experiences. The staff must work together as a unit.

It is obvious that a substantial proportion of the faculty teaching the technical specialty courses be graduate engineers. Experience has shown that engineering technology graduates who have acquired industrial experience and have continued their education often make excellent teachers in this type of program. If the curriculum is to keep pace with technology, it is not feasible to depend to any great extent upon faculty members whose technical competence is only slightly greater than that of the students. The use of an unduly large number of part-time faculty members is undesirable.

Faculty members must maintain technical competence and should be encouraged to participate in the activities of professional and technical societies. They should also be encouraged to keep up with the literature in their field, continue their education, and maintain close liaison with industry in the area of their specialities by working summers. This encouragement is most effectively provided in the form of released time and financial assistance whenever possible.

Teaching loads should be based on contact hours rather than credit hours since, in general, this type program requires the faculty member to spend a greater number of hours with the student per credit hour than do some other types of educational programs. Promotions should be based on a balanced judgment of the instructor's ability to bring a broad experience and academic background to bear on his students, rather than solely on the acquisition of higher academic degrees.

Student Selection

While the effectiveness of an engineering technology program depends greatly upon the quality of the faculty, its success depends even more heavily on the quality of its graduates. It is essential, therefore, that the students accepted into the program be capable of successful accomplishment of the educational objectives of the program. If the incoming students' backgrounds are inadequate, instructors will tend to adjust their courses to these inadequacies. The inevitable result will be a program of depth and scope less than that implied by the curriculum and a lack of utilization of faculty capabilities.

Any discussion of academic standards, therefore, must be preceded by a statement of admission requirements and student selection. The assumption on which this suggested curriculum is based, is that the incoming students have been graduated from an accredited secondary school or have an equivalent education. In addition, the student should exhibit some evidence of sufficient ability and the necessary aptitudes for satisfactory achievement in the program.

In the opinion of the committee, a satisfactory engineering technology program requires the following minimum secondary school units:

a) Three units of English. These should provide the student with the basic tools of effective communication.
b) Two units of Mathematics. One unit in algebra and the other in plane geometry (or the equivalent of these in integrated mathematics).
c) One unit in Physical Science. Whenever possible, this unit should be either in physics or chemistry.

Students entering without these minimum secondary school units should not expect to complete the program in the allotted time. If such students are admitted, non-credit courses in these areas should be provided to bring the student to the required level of proficiency in these areas.

Transfer of credit from other institutions should be evaluated realistically on the basis of comparative course content and objectives. They may be validated, if in question, by reliable proficiency examinations. Automatic acceptance for credit without adequate evaluation should be avoided.

Student Services

Whenever possible, institutions offering engineering technology programs should consider the use of standardized or local tests to assist in student selection, placement, and guidance. Effective guidance and counseling is essential. The student should be aided in selecting educational and occupational objectives consistent with his interests and aptitudes. He should be advised to revise his educational objectives if it becomes apparent that he is more suited to other programs, either in engineering, or vocational training, or another technology.

The graduate should be given all possible assistance in finding suitable employment. Placement personnel should be aware of the needs of industry, familiar with the curricula offered by their institution, and should be in a position to acquaint prospective employers with the various types of positions for which their graduates are qualified. The placement function is extremely valuable, to the student, the institution, and industry.

The Electronic Technology Curriculum

(Six - Quarter Programs)

The Curriculum Summary

Table I, entitled, "Curriculum Summary in Clock Hours and Credit Hours," shows the relative proportion of the time devoted to basic science, nontechnical and technical courses. These proportions are in keeping with the recommendations of the ASEE report entitled, Characteristics of Excellence in Engineering Technology Education, published in 1962 under the direction of James L. McGraw.

The courses in the curriculum (page 10) have been structured in accordance with the generally accepted system of requiring three hours of effort per week on the part of the student for each credit hour. The three hours per week include work performed in the classroom, laboratory, homework, or any combination thereof. In general, one credit hour is given for one hour of class lecture that requires two hours of home preparation. A two hour laboratory requiring one hour of home preparation is equivalent to one credit hour. A three hour laboratory session for one credit hour does not require any outside preparation. On this basis, an 18 credit hour is a reasonable academic load for the average student to carry in any one term.

In some of the courses of this curriculum, especially those with laboratory hours, it is expected that some of the laboratory time shall be used for supervised problem solving in lieu of home study time.

TABLE 1

Curriculum Summary in Clock Hours and Credit Hours

	Clock Hours	Quarter Credit Hours	Semester Credit Hours
Basic Science Courses			
Mathematics	198	18	12
Physics	165	12	8
	363	30	20
Non-Technical Courses			
Communications	110	10	6.67
Humanistic-Social Studies	143	13	8.67
	253	23	15.34
Technical Courses			
Technical Skills	220	6	4
Technical Specialty	946	50	33.33
	1166	56	37.33
Totals	1782	109	72.67

Program Objectives

The two-year electronic technology curriculum is constructed to meet the specific objectives of an engineering technology curriculum. These objectives were presented in preceding paragraphs. The engineering technician should have a broad range of competencies. He should have the abilities to design, assemble and test electronic circuits. He should have the ability to assist engineers and scientists in projects of development and research.

This two-year electronic technology curriculum is constructed as a fundamental and practical type of program to satisfy the prerequisites that will qualify the graduate to perform job functions in any one of a number of options such as communications, control systems, computer design, computer applications, industrial electronics, data processing, electronic drafting, logic systems, circuit design, system testing and measurement techniques. An additional one or two quarters for purposes of further specialization and continuing education is strongly recommended.

An electronic technology curriculum should have a proper balance between theory and practice. The theory portion of the program requires a working knowledge of mathematics through calculus along with some differential equations and an ability to analyze a variety of circuits. For many years mathematics has determined the sequencing of topics in the circuits and electronics courses. The practical portion of the program requires a knowledge of instruments, testing and measurement techniques along with an ability to recognize and solve practical problems as actually confronted in industry.

Unique Features

The curriculum is designed to meet the objectives of the two-year six quarter program. The complete curriculum, as shown on page 10, has a number of unique features. The flow chart of Fig. 1 shows how the technical specialty portion of the program and the mathematics courses are interrelated.

1. The two courses, Introductory Electronics I and II, in the first and second terms respectively, are designed to acquaint the student with the content of the electronic technology curriculum through laboratory projects that are done qualitatively rather than on an analytical basis.

Introductory Electronics I introduces the student to measuring instruments most commonly used throughout the curriculum. Emphasis is on quantities which an instrument is capable of measuring. The details and procedures for this exploratory course are defined in the outline.

Introductory Electronics II provides an opportunity to explore the operation and response of the most common types of basic electronic circuits that serve as building blocks for practical electronic systems. The course is exploratory and qualitative analysis is emphasized. It provides the practical experience and the motivation for the detailed and quantitative studies that follow in the curriculum.

2. The seminar sessions in the last five quarters of the curriculum are designed to provide additional enrichment for the students. This should be accomplished by providing guest lecturers from industry, touring industries, viewing technical films, and through the discussion of topics pertinent to the electronic technology curriculum.

3. Circuits I (Resistive Circuits) provides the basic concepts for continued circuit analysis. The study of resistive circuits requires algebra and some trigonometry which are covered in Mathematics I in the first quarter. This course serves as a prerequisite to Electronics I (Resistive Electronics) which comes in the following quarter. Refer to the flow chart in Fig. 1.

Circuits II (Single Time Constant Circuits) requires an understanding of only basic concepts of calculus. It serves as a natural introduction to Electronics II (Pulse Circuits) which comes in the following term. The circuits courses beyond Circuits II are presented in the traditional manner. Circuits III (Network Analysis), for example, is a traditional treatment of circuits, which covers general and advanced circuits and has no restrictions as in Circuits I and Circuits II.

4. There is a sequence of three electronic courses, starting in the third quarter. They emphasize the quantitative analysis and include a detailed study of electronic circuits. They

are identified as: Electronics I (Resistive Electronics), Electronics II (Pulse Circuits) and Electronics III (Advanced Electronics). These three courses in electronics follow a natural sequence that is integrated and sequenced in accordance with the background knowledge from the courses in the circuits area as well as from the mathematics area. For example: Electronics I (Resistive Electronics) follows Circuits I (Resistive Circuits) which, in turn, follows Mathematics I. The flow diagram of Fig. 1 shows the sequencing of the basic courses. Observe the heavy diagonal lines that slant downward from right to left, from the mathematics area to the circuits area to the electronics area.

5. The technical electives of the fifth and sixth quarters provide a degree of flexibility. Five areas of specialization are recommended as possibilities. A particular educational institution may wish to offer no more than one of these areas of specialization, in accordance with instructional talents and in accordance with the particular needs of industry.

The footnote at the close of the curriculum, page 11, gives the recommended courses for each of the five areas of specialization. More detailed information is presented in an appropriate place later in the guide. Refer to the Table of Contents where each area is identified as an option.

6. This six-quarter curriculum provides at least two natural "break-off" points. After a student completes the first two quarters, he will have had the two introductory electronics courses and the two drafting courses that will provide employment opportunities especially as a draftsman or as a maintenance technician. The courses of the first quarter could also be used in a vocational program that leads to a certificate or a diploma.

7. The physics courses are outlined to reflect the present-day philosophy as to contents and sequencing of topics for a one-year comprehensive terminal course. The physics sequence serves as the basic science course in the electronic curriculum. It is introduced in the third quarter after the student has been introduced to the fundamentals of calculus. It follows an outline which is independent of the topic sequencing of electronic material.

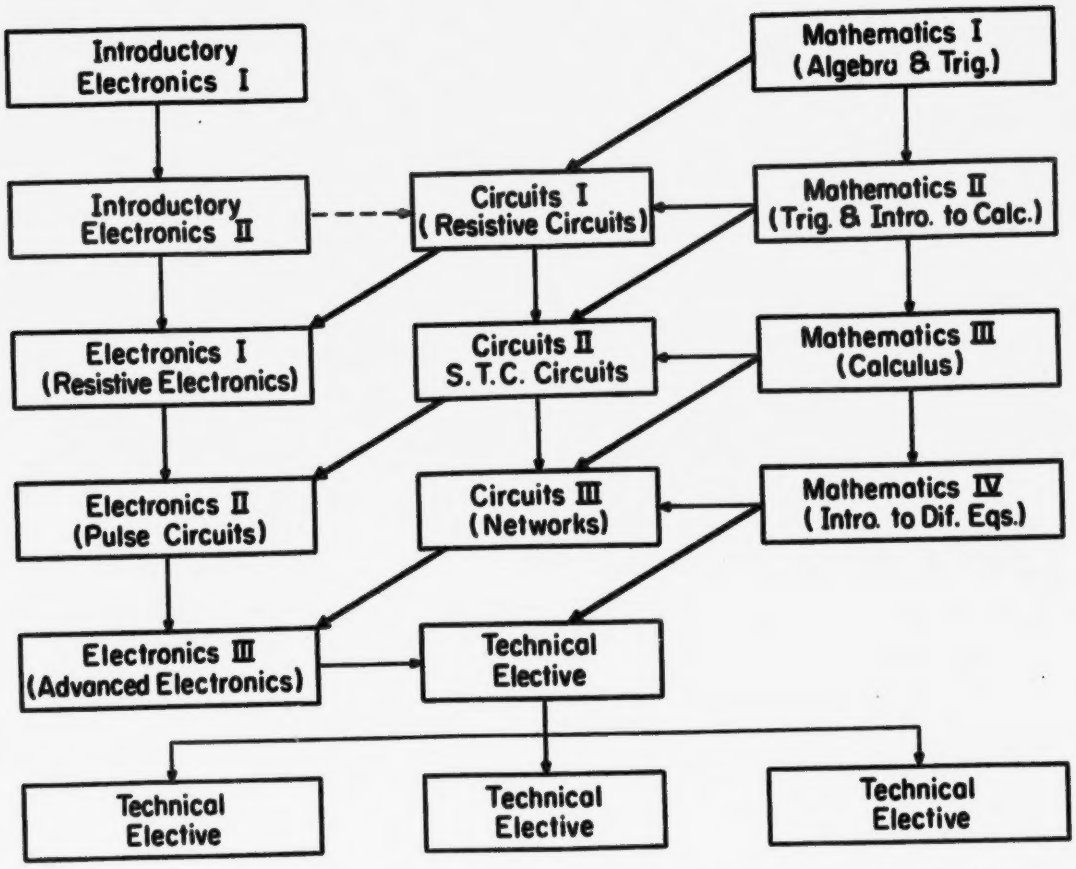
Introductory Electronics I
Mathematics I (Algebra & Trig.)
Introductory Electronics II
Circuits I (Resistive Circuits)
Mathematics II (Trig. & Intro. to Calc.)
Electronics I (Resistive Electronics)
Circuits II S.T.C. Circuits
Mathematics III (Calculus)
Electronics II (Pulse Circuits)
Circuits III (Networks)
Mathematics IV (Intro. to Dif. Eqs.)
Electronics III (Advanced Electronics)
Technical Elective
Technical Elective
Technical Elective
Technical Elective

Fig. 1 Flow Chart for Mathematics, Circuits, Electronics and Technical Elective Courses

Use of Textbooks

Recommendations as to texts and references are presented at the close of each course outline. For some of the courses, one or more of the recommended texts may be completely satisfactory. On the other hand, it might not be possible to find one particular text that will cover a course content as outlined. In such instances it becomes necessary to supplement a selected textbook with specially prepared material. It may even be necessary to have more than one textbook or to have a good set of references in sufficient quantity to satisfy the needs. There is a great need for new books that are specifically written for an electronic technology curriculum, especially for the technical specialty portion of the program. A number of appropriate books are becoming available in increasing numbers. Special thanks are extended to a number of publishers who have provided examination copies of recent books in order that the recommended texts and references could be brought up to date.

Laboratory Instruction

Performance in the laboratory should serve two general objectives. One of the major objectives is to provide the student a practical environment for the investigations and studies relating to the theory presented in the class-hour sessions. The second major objective is to provide the student with sufficient practical information and competence to make the graduate productive as an employee in industry with a minimum of training required by industry. The following specific objectives of laboratory work are significant. (From: Circuit Analysis by Laboratory Methods by C. E. Skroder and M. S. Helm, Prentice-Hall, Inc., second edition, 1955.)

1. To develop the power of analysis and synthesis.
2. To develop initiative, ingenuity, self-reliance and resourcefulness.
3. To develop the ability to visualize a physical circuit from a schematic diagram.
4. To give experience in making circuit connections and in using instruments and control devices.
5. To verify theory by experiment.
6. To develop the facility of organized self-expression in writing and data taking.
7. To develop the ability to analyze and interpret experimental data.
8. To develop an appreciation of the limitations of data obtained by measurement.

Special significance is placed on two concepts of laboratory utilization: Introductory Laboratory and Open Laboratory. The Introductory Laboratory is designed to acquaint the student with instrument operation and characteristics of operation of a select number of circuits. The work with instruments is a "hands-on-approach" to acquaint the student with the operational capabilities of the instruments found in the laboratory. The work with the selected circuits emphasizes external characteristics when the individual circuit parameters are changed.

The Open Laboratory incorporates a special area for fabrication processes plus the standard equipment for an electronics laboratory. This laboratory is for use by students and staff for fabrication processes. The activity in this area would be carried on during and outside of class time. Participation in the development of electronic projects requiring the use of the shop is encouraged by the entire staff.

Laboratory Equipment

Laboratory equipment and instruments should be carefully selected to best satisfy the objectives of an electronic technology curriculum. These objectives require the use of good instruments to permit the student to make the wide range of measurements required in the curriculum. In general, the instruments should be those that are acceptable for use in industry.

A suggested list of instruments, giving a cost range, is presented in Appendix C. The costs for furniture, small parts and components are also listed in this appendix. The costs for equipping the laboratories for the circuits courses and for the electronics courses are listed separately for convenient reference. The summary of costs, part C of this appendix, reveals a total possible cost that falls within the range of $91,330 to $173,400 when the laboratory for the three required circuits courses and the laboratory for the five required electronics courses are conducted in separate areas. When combined into one laboratory area, however, tht total cost reduces to the range of $64,315 to $116,300.

Laboratory Space and Facilities

Laboratory space requirements are presented in Appendix A. Recommendations pertaining to furniture and work benches are presented in Appendix B. Assuming ten work stations for a laboratory area, the criteria are:

1. Two students per work station is considered ideal. Each laboratory area will handle up to twenty students in any one laboratory period.

2. Each work station should have its own laboratory table. Lengthy benches that do not separate the work stations are discouraged.

3. The laboratory tables should be arranged to make it convenient for the instructor to observe the progress of all students. Some recommended layouts are suggested by the Figs. D-1 through D-4 of Appendix D.

4. Calculating tables should be provided for convenience to the students.

5. Chalk boards should be convenient to all work stations for convenience to the students in discussing their laboratory problems.

6. A separate area, near the main laboratory, should be available to the student for special construction and assembly projects.

7. There should be a separate area for maintenance of equipment and for repairs, available especially to the instructors and shop personnel.

8. A storage area should be provided where supplies and instruments can be secured under lock and key.

Special Shop Area

Manipulative skills in the operation of machine tools, as well as maintenance and assembly techniques applicable to electronic equipment, are essential parts of the complete educational program. A special open shop area is recommended for this purpose. The shop area is a place where certain machine tools and special work areas are available to the student for special individual or group projects.

SUGGESTED TWO-YEAR ELECTRONIC TECHNOLOGY CURRICULUM

Course	Hours			
	Class	Laboratory	Contact	Credit
1st Quarter				
Mathematics I (Algebra & Trig.)	5	0	5	5
Introductory Electronics I	1	4	5	2
Communications I	4	0	4	4
Mechanical Drafting	1	6	7	3
Psychology of Human Relations	4	0	4	4
Orientation	0	0	1	0
	15	10	26	18
2nd Quarter				
Mathematics II (Trig. & Introduction to Calculus)	5	0	5	5
Introductory Electronics II	1	4	5	2
Circuits I (Resistive Circuits)	4	2	6	5
Communications II	3	0	3	3
Electronic Drafting	1	6	7	3
Seminar	0	0	1	0
	14	12	27	18
3rd Quarter				
Mathematics III (Calculus)	5	0	5	5
Electronics I (Resistive Electronic Circuits	3	4	7	4
Circuits II (S.T.C. Circuits)	4	4	8	5
Physics I	3	2	5	4
Seminar	0	0	1	0
	15	10	26	18
4th Quarter				
Mathematics IV (Introduction to Differential Equations)	3	0	3	3
Electronics II (Pulse Circuits)	3	4	7	4
Circuits III (Network Analysis)	3	4	7	4
Physics II	3	2	5	4
Industrial Organization and Operation	3	0	3	3
Seminar	0	0	1	0
	15	10	26	18

Course	Hours			
	Class	Laboratory	Contact	Credit
5th Quarter				
Electronics III (Advanced Electronics)	4	4	8	5
Physics III	3	2	5	4
Technical Report Writing	3	0	3	3
Technical Elective(1)	3	4	7	4
Economics of Industry	3	0	3	3
Seminar	0	0	1	0
	16	10	27	19
6th Quarter				
Technical Elective(1)	3	4	7	4
Technical Elective(1)	3	4	7	4
Technical Elective(1)	3	4	7	4
Circuits IV (System Analysis)	1	4	5	3
Nontechnical Elective	3	0	3	3
Seminar	0	0	1	0
	13	16	30	18

(1) The technical electives should be electrical courses of some one area of specialization as desired for a particular program. A few possible courses and areas are:

- Power Option (See Page 68)
  - Advanced Power Circuits
  - Rotating Machinery
  - Power Distribution Systems
  - Electrical Design
- Computer Option (See Page 71)
  - Computer Logic
  - Computer Programming
  - Measuring Principles (Mechanical and Electrical)
  - Analog Computers
- High Frequency Communication and Transmission Options (See Page 73)
  - Fields and Waves
  - Transmission Lines
  - Microwave Fundamentals
  - UHF Communication and Reception
  - Antennas
- Instrumentation Option (See Page 75)
  - Measuring Principles (Mechanical and Electrical)
  - Control Principles and Telemetry
  - Standards and Calibration
  - Computer Programming
- Industrial Control Systems Option (See Page 77)
  - Industrial Control Circuits and Components
  - Computer Programming
  - Servomechanism
  - Measuring Principles

COURSE OUTLINES

ORIENTATION*

HOURS REQUIRED

Class - 1; Credit - 0.

DESCRIPTION

A brief review of the field of occupations is followed by a discussion of the life work of technical personnel, the part that interests and aptitudes play in the successful attainment of vocational goals, and how one goes about evaluating these qualities. Field trips give the student the opportunity to see the electronic technician in action, while individual interviews give the instructor firsthand information about the student.

INSTRUCTION PROCEDURE

Movies or other training aids could be used to supplement or replace field trips if they are not feasible. Guest lecturers from industry should be invited to take part in the program. These men would provide the student with valuable future contacts and would give him the employer's attitudes towards the technician and his place in the industry. It is recommended that the student submit reports on the field trips that are made.

MAJOR DIVISIONS

		Class Hours
I.	The School	1
II.	Technical Personnel	4
III.	The Program of Study	2
IV.	Field Trips	3
V.	Individual Counseling	1
		11

I. The School
  Class: 1 hour
  1. Purpose of orientation
  2. The technical institute, its place in education, the associate degree, accreditation
  3. How and when to study
  4. What is counseling, where is it obtained
  5. Scholarship and assistance programs

II. Technical Personnel
  Class: 4 hours
  1. The world of work
     a. Occupational levels and preparation
     b. Qualifications for typical occupations
  2. Aptitudes required in electronic technology
  3. Assessing personal aptitudes--guidance and testing
  4. Nature of technician work
     a. The engineering team
     b. Typical work of the technician
     c. Departments in industrial concerns employing technicians
  5. Job opportunities
     a. Wages
     b. Promotional possibilities
     c. Local industrial scene in electronic technology
     d. Further schooling
  6. Employment practices
     a. Recruitment
     b. Tests
     c. Interviews
     d. School placement department

III. The Program of Study
  Class: 2 hours
  1. Purpose of courses
     a. General education
     b. Related subjects
     c. Technical subjects
  2. Arrangement of the curriculum
     a. Designing major
     b. Manufacturing major
  3. The grading system and tests
  4. Opportunities in noninstitute courses

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*Adapted from USOE publication No. OE-80019 "Mechanical Technology - Design and Production."

    5. Extracurricular activities
    6. The curriculum planning sheet--a guide to each semester's program

IV. Field Trips

Class and Field: 3 hours

1. Preparation for trips to nearby industries; what to look for, type of questions to be asked of engineers
2. Tours planned specifically to show the technician at work
3. Discussion of trips, conclusions that may be drawn
4. Reports are prepared and submitted for each field trip made

V. Individual Counseling

Class: 1 or more hours, as required

1. Establish rapport with each student, discussion of individual's objectives, aptitudes, progress in school to date, study habits, etc.
2. Schedule further counseling sessions as needed
3. Arrange for the services of others (school psychologist, testing department, other technical area instructor if student is uncertain of interest in electrical engineering technology)

SOME SUGGESTED TEXTS AND REFERENCES

Bergen, Jay H., Putting Technicians to Work, U. S. Department of Health, Education and Welfare, Washington, D. C.

National Association of Manufacturers, Your Opportunities in Industry as a Technician, The Association, 2 East 48th Street, New York 17, N. Y.

Staton, Thomas, How to Study, McQuiddy Printing Co., Nashville, Tennessee

Current magazine and newspaper articles

SOME SUGGESTED VISUAL AND TRAINING AIDS

Coronet Films, Coronet Building, Chicago, Illinois
- Aptitudes and Occupations
- Your Earning Power
- Mechanical Aptitudes

Encyclopaedia Brittanica Films, Inc., 1150 Wilmette Avenue, Wilmette, Illinois:
- Planning your Career

Iowa State University, Ames, Iowa:
- Getting Acquainted with Engineering

Vocational Guidance Films, Des Moines, Iowa:
- Engineering

Charts and graphs illustrating employment trends in industry

Job classification and qualification charts

Sample intelligence, aptitude and personality tests

Programmed Learning Report, Engineering Education, ASKE, Feb. 1967

Video Tape Recorders

MATHEMATICS I

(Algebra and Trigonometry)

HOURS REQUIRED

Class - 5; Credit - 5.

DESCRIPTION

This course includes algebra, vectors, and an introduction to trigonometry.

INSTRUCTION PROCEDURE

The first course in mathematics is designed to equip students with operational methods necessary for the understanding of concurrent technical courses. It is also designed to give students skills to successfully complete more advanced mathematics courses. Supplementary notes may be required to support selected texts.

MAJOR DIVISIONS

		Class Hours
I.	Review of Fundamental Operations	5
II.	Advanced Algebra	15
III.	Theory of Equations	15
IV.	Fundamentals of Trigonometry	15
V.	Vectors	5
		55

I. Review of Fundamental Operations
  Class: 5 hours
    1. Modular number systems
    2. Laws of algebra
    3. Functions and graphs
    4. Equations
    5. Metric units and scientific notation

II. Advanced Algebra
  Class: 15 hours
    1. Ratio, variation, and progressions
    2. Fractions and radicals
    3. Exponential functions
    4. Logarithms

III. Theory of Equations
  Class: 15 hours
    1. Synthetic division
    2. Equation theorems
    3. Binomial theorem
    4. Roots of equations
    5. Systems of equations

IV. Fundamentals of Trigonometry
  Class: 15 hours
    1. Radian measure
    2. Trigonometric functions
    3. Signs of the trigonometric functions
    4. Trigonometric tables
    5. The right triangle

V. Vectors
  Class: 5 hours
    1. Vector addition
    2. Resolution of forces
    3. Application of vectors

SOME SUGGESTED TEXTS AND REFERENCES

(See listing with Mathematics III)

MATHEMATICS II

(Trig. and Introduction to Calculus)

HOURS REQUIRED

Class - 5; Credit - 5.

DESCRIPTION

This course contains selected topics in algebra, trigonometry and analytic geometry.

INSTRUCTION PROCEDURE

Selected topics in analytic geometry are introduced to provide the student with prerequisite skills necessary to understand the calculus.

A brief introduction to the derivative is provided at the end of the second quarter to increase the student's awareness of the calculus as a powerful tool in the solution of advanced technical problems.

Supplementary notes may be required to support selected texts.

MAJOR DIVISIONS

	Class Hours
I. Properties of Trigonometric Functions	15
II. The Algebra of Complex Numbers	15
III. Analytic Geometry	15
IV. The Derivative	10
	55

I. Properties of Trigonometric Functions
Class: 15 hours
1. Trigonometric functions of any angle
2. Laws of sine and cosine
3. Sum and difference of two angles
4. Double and half-angle formulas
5. Fundamental trigonometric identities
6. Trigonometric equations
7. Inverse trigonometric functions

II. The Algebra of Complex Numbers
Class: 15 hours
1. Real and complex numbers
2. The complex plane
3. Addition and subtraction of complex numbers
4. Exponential, trigonometric, and polar form of complex numbers
5. Products, quotients, powers, and roots of complex numbers

III. Analytic Geometry
Class: 15 hours
1. Basic definitions
2. The straight line
3. The conic section

IV. The Derivative
Class: 10 hours
1. Limits
2. The delta process
3. Derivatives of polynomials

SOME SUGGESTED TEXTS AND REFERENCES

(See listing with Mathematics III)

MATHEMATICS III

(Calculus)

HOURS REQUIRED

Class - 5; Credit - 5.

DESCRIPTION

This course presents an introduction to the basic principles of differential and integral calculus.

INSTRUCTION PROCEDURE

This course is designed to introduce to students sections of the calculus necessary to understand advanced technical courses. Lack of time in the two-year technical program prohibits the use of a more traditional mathematics approach.

MAJOR DIVISIONS

	Class Hours
I. The Derivative	10
II. Integration I	10
III. Differentiation of Transcendental Functions	10
IV. Integration II	15
V. Series Expansions	10
	55

I. The Derivative
Class: 10 hours
1. Derivatives of products and quotients
2. Derivatives of a function of a function
3. Maximum and minimum problems

II. Integration I
Class: 10 hours
1. Integration as the inverse of differentiation
2. The indefinite integral
3. The definite integral
4. Finding areas by integration
5. Approximate methods of integration

III. Differentiation of transcendental functions
Class: 10 hours

1. Derivatives of the trigonometric functions
2. Derivatives of the exponential functions
3. Derivatives of the logarithmic functions

IV. Integration II
Class: 15 hours

1. Integration of a function to a power
2. Exponential forms
3. Logarithmic forms
4. Trigonometric forms
5. Integration by parts
6. Integration by use of tables

V. Series Expansions
Class: 10 hours

1. The Maclaurin series
2. The Taylor series
3. The Fourier series

SOME SUGGESTED TEXTS AND REFERENCES

Adams, L. J., Applied Calculus, John Wiley & Sons, New York, N. Y., 1963

Amramowitz, Milton, Handbook of Mathematical Functions, U. S. Government Printing Office, Washington, D. C., 1965

Andrews, Allan, Practice Problems in Electronics Calculations, Howard W. Sams and Company, Inc., New York, N. Y., 1964

Andrews, Allan, Electronics Math Simplified, Vol. I, Howard W. Sams and Company, Inc., New York, N. Y., 1964

Andrews, Allan, Electronics Math Simplified, Vol. II, Howard W. Sams and Company, Inc., New York, N. Y., 1964

Andris, Paul G., Miser, Hugh J., Reingold, Haim, Basic Mathematics for Science and Engineering, John Wiley and Sons, New York, N. Y., 1955

Cooke, Nelson, Basic Mathematics for Electronics, McGraw-Hill Book Co., New York, N. Y., 1960

Crowhurst, Norman H., Mathematics for Electronics Engineers and Technicians, Howard W. Sams and Co., New York, N. Y., 1964

Dodes, Irving Allen, I.B.M. 1620 Programming for Science and Mathematics, Hayden Book Co., New York, N. Y., 1963

Evens, Paul L., Mathematics for Electronics Technicians, John Wiley and Sons, New York, N. Y., 1966

Gillie, A. C., Binary Arithmetic and Boolean Algebra, McGraw-Hill Book Co., Inc., New York, N. Y., 1965

I.T.T. Federal Electric Corporation, Mathematics for Electronics, Prentice-Hall, Inc., Englewood Cliffs, N. J., 1965

Lytel, Allen, Calculus for Electronics Technicians, D. Van Nostrand Co., New York, N. Y., 1964

Maidel, George F., Basic Mathematics for Television and Radio, Prentice-Hall, Inc., Englewood Cliffs, N. J., 1953

Paull, Stephen, Topics in Advanced Mathematics for Electronics Technology, John Wiley and Sons, New York, N. Y., 1966

Person, R. B., Elements of Mathematics, John Wiley, New York, 1966

Placek, R. J., Technical Mathematics with Calculus, Prentice-Hall, Inc., Englewood Cliffs, N. J., 1967

Rice, Harold S., Knight, Raymond M., Technical Mathematics with Calculus, McGraw-Hill Book Co., Inc., New York, N. Y., 1966

Rice, Harold A., Technical Mathematics; Exercises, Problems, Diagrams, Tables, McGraw-Hill Book Co., Inc., New York, N. Y., 1963

Scade, Samuel, Mathematics for Technical and Vocational Schools, John Wiley & Sons, New York, N. Y., 1955

Singer, Bertrand B., Basic Mathematics for Electricity and Electronics, McGraw-Hill Book Co., Inc., New York, N. Y., 1965

Washington, Allyn J., Basic Technical Mathematics with Calculus, Addison-Wesley Publishing Co., Inc., Reading, Mass., 1964

Wolf, O. and Lattner, C. G., Mathematics for Electronics, ITT Federal Electric Corporation, Prentice Hall, Inc., Englewood Cliffs, New Jersey, 1965

MATHEMATICS IV

(Introduction to Diff. Equations)

HOURS REQUIRED

Class - 5; Credit - 5.

DESCRIPTION

This course contains an introduction to differential equations and the Laplace transform.

INSTRUCTION PROCEDURE

Selected topics in differential equations are introduced. The student should acquire the skill necessary to solve simple second-order homogeneous differential equations with constant coefficients. It is not necessary that the student solve all types of differential equations. It is only important that the student be able to write the differential equations, determine the initial conditions, and apply the correct Laplace transform to yield the solution.

MAJOR DIVISIONS

	Class Hours
I. Differential Equations	15
II. Laplace Transforms	18
	33

I. Differential Equations
  Class: 15 hours
  1. Definition of the differential equation
  2. Linear differential equations of the first order
  3. Second-order homogeneous equations with constant coefficients
  4. Elementary applications

II. Laplace Transforms
  Class: 18 hours
  1. Definition of the Laplace transform
  2. Construction of a Laplace transform table
  3. Partial fraction expansion
  4. The inverse of the Laplace transforms
  5. Solutions of problems with the Laplace transforms

SOME SUGGESTED TEXTS AND REFERENCES

(See listing with Mathematics III)

INTRODUCTORY ELECTRONICS I

HOURS REQUIRED

Class - 1; Laboratory - 4; Credit - 2.

DESCRIPTION

Introductory Electronics I is designed to provide familiarization with laboratory instruments, circuit components, and basic measurement techniques.

INSTRUCTION PROCEDURE

The instruments to be studied, the projects to be performed, and the procedures to be followed are presented in the course outline.

Supplementary notes may be required to support selected texts.

MAJOR DIVISIONS

	Class Hours	Laboratory Hours
I. Voltage: Measurement and Sources	3	12
II. Circuit Components and Their Measurement	3	12
III. Current, Power, and Their Measurement	2	8
IV. Dependent Sources (Amplifiers)	1	4
V. Special Topics	2	8
	11	44

I. Voltage: Measurement and Sources

Defines in a general manner the terms voltage and waveform. Shows that an oscilloscope and various meters measure voltage, and introduces voltage sources of all types.

- A. Class: 3 hours
  - 1. Principles of the oscilloscope and how it is used to measure voltage waveforms
  - 2. Voltage sources
    - a. Battery and constant voltage supplies
    - b. Sinusoidal, audio and RF generators
    - c. Other voltage waveforms; pulse, ramp, and triangle
  - 3. Voltmeters and measurements
    - a. Types, ranges, terminal markings, and connection in circuit
    - b. Measurement of constant voltage, sinusoidal, and other voltage waveforms
    - c. Introduction to concepts of average, RMS, peak, and peak-to-peak voltage measurements
- B. Laboratory: 12 hours
  - 1. Study and operation of the oscilloscope
    - a. Intensity and focus controls
    - b. Vertical and horizontal positioning
    - c. Sweep rates and synchronization of traces
    - d. Amplitude and time measurement
    - e. Dual sweep control systems
  - 2. Study of voltage sources with the use of the oscilloscope
    - a. Study of each voltage source individually; measuring and recording waveforms
    - b. Study of superimposed voltage waveforms by connecting various voltage sources in series
    - c. Use of two sinusoidal sources to obtain Lissajous patterns and introduction to the concept of harmonics
  - 3. Study of voltmeter readings compared to the oscilloscope
    - a. Use of various voltmeters to measure voltage sources and comparison of various meter readings in conjunction with the cathode ray oscilloscope

II. Circuit Components and Their Measurement

Define in a general manner (without the use of formulas) resistance, capacitance, and inductance.

- A. Class: 3 hours
  - 1. Resistance
    - a. Color code, standard sizes, ratings, structural types, resistance attenuators, potentiometers, and thermistors
    - b. Ohmmeters and resistance bridges
  - 2. Capacitance
    - a. Standard sizes, ratings, and structural types
    - b. Capacitor checker and bridges
    - c. Demonstration of the capacitor's opposition to an instantaneous change in voltage
  - 3. Inductance
    - a. Standard sizes, ratings, and structural types
    - b. Bridge measurements
    - c. Demonstration of the inductor's opposition to an instantaneous change in current
- B. Laboratory: 12 hours

The student should gain a feeling for the physical properties of the three circuit components above, along with some relationship between series and parallel combinations.

- 1. Resistance
  - a. Color code and the use of the ohmmeter
  - b. Bridge measurements
  - c. Series and parallel combinations
- 2. Capacitance
  - a. Color code and the use of the capacitor checker
  - b. Bridge measurements
  - c. Ohmmeter checks for D-C continuity
  - d. Series and parallel combinations
  - e. Charging and discharging a capacitor, and charging and discharging of series and parallel combinations
- 3. Inductance
  - a. Standard sizes and bridge measurements
  - b. Checks with ohmmeter for D-C continuity
  - c. Series and parallel combinations
  - d. Placing two inductors close together, one connected to a sinusoidal source and the other to the oscilloscope, and introduction of the concept of induced voltages and transformers
  - e. Use of ohmmeter to study R-L and R-C series circuits and introduction to time constants

III. Current, Power, and Their Measurement

- A. Class: 2 hours
  - 1. Define in a general manner current flow, current controlling devices (R, L, and C), and the use of the ammeter
  - 2. Define power from a work-energy point of view, and show the relationship between watts, volts, amperes, and ohms
- B. Laboratory: 8 hours

The student should use all previous laboratory equipment in the study of current flow and power, like, for example, monitoring the circuit with both voltmeter and the oscilloscope.

- 1. Current measurements
  - a. Types of ammeters, selection of proper meter, and method of connecting them in the circuit
  - b. Summing of currents in a resistive network to yield source current using both a constant source and a sinusoidal input
  - c. Summing of currents in a R-L-C network to yield source current using both a constant source and a sinusoidal input
  - d. Summing of currents to yield source current with a R-L-C network having a sinusoidal input at different frequen-

cies, and observing voltage drops as well as current flow as the frequency is varied
    - e. Use of voltage drop across a resistor to show current waveform. The student should use the dual trace oscilloscope to study current and voltage waveforms in a R-L-C network
- 2. Power measurements
    - a. Types of wattmeters, selection of proper meters and methods of connecting them in circuits
    - b. Analysis of resistive circuits by means of the ohmmeter, voltmeter, ammeter, and wattmeter
    - c. Power measurement of purely reactive circuit

IV. Dependent Sources (Amplifiers)
- A. Class: 1 hour
    - 1. Examine dependent and independent sources, and show how transsistors and vacuum tubes are used as amplifiers
- B. Laboratory: 4 hours

The student is to study preassembled transistor and vacuum tube amplifier circuits. Theory regarding the parameters of these circuits should be kept to a minimum.

- 1. Study of voltage amplification in conjunction with various independent voltage sources studies above, including an introduction to distortion
- 2. Study of voltage amplification with microphone input and an earphone load, in conjunction with the oscilloscope

V. Special Topics

Students should become familiar with special pieces of equipment in the laboratory. Rotation of students on equipment may be necessary at this point. Examples of such equipment are the wave analyzer, distortion analyzer, vector impedance meter, spectrum analyzer, and oscilloscope photography instruments.

- A. Class: 2 hours
- B. Laboratory: 8 hours

SUGGESTED TEXTS AND REFERENCES

Instruction and maintenance manuals on all pieces of laboratory equipment are necessary. Each student should have a manual checked out to him as he proceeds through the laboratory equipment in the course.

The course will require hand-out material from the instructor.

INTRODUCTORY ELECTRONICS II

HOURS REQUIRED

Class - 1; Laboratory - 4; Credit - 2.

COURSE DESCRIPTION

Introductory Electronics II is designed to acquaint the student with basic circuits used as building blocks in any electronics system. It is the arrangement and the interaction of these basic circuits that determine the end product which is called a system.

INSTRUCTION PROCEDURE

Circuits used by the student in the laboratory are permanently assembled. (Circuit boards or block systems are used allowing the student to study the circuit and its components; he may adjust a variable resistor or change a jumper wire, but the circuits are basically preassembled.) Circuit diagrams, along with defined circuit parameters, should always be furnished.

The circuits should be approached from a response point of view along with their name and application. The reading of circuit diagrams should be encouraged from the very beginning.

After the student has studied a series of individual circuits in the laboratory, block diagrams of systems should be introduced giving applications of the circuits and illustrating the concept of electronic systems.

MAJOR DIVISIONS

		Class Hours	Laboratory Hours
I.	Rectifiers and Power Supplies	1	4
II.	Amplifiers	1	4
III.	Oscillators	1	4
IV.	Modulation and Detection	2	8
V.	Multivibrators and Trigger Circuits	2	8
VI.	Gating Circuits	1	4
VII.	Sweep Circuits	1	4
VIII.	Systems	2	8
		11	44

I. Rectifiers and Power Supplies
  A. Class: 1 hour
    1. Qualitative discussion of rectifiers and power supplies as to types, circuit diagrams, etc.
  B. Laboratory: 4 hours
    1. Half-wave rectifier circuit
      a. Plot input and output waveforms with and without a filter network
      b. Loading effect and ripple factor
    2. Same for full-wave rectifier and a voltage doubler circuit

II. Amplifiers
  A. Class: 1 hour
    1. Qualitative discussion of amplifiers as to types, circuit diagrams, etc.
  B. Laboratory: 4 hours
    1. R-C coupled amplifier
      a. Biasing and signal requirements
      b. Distortion of output when overdriven
      c. Frequency response
    2. Same for cathode follower
    3. Same for tuned RF amplifier

III. Oscillators
  A. Class: 1 hour
    1. Defined in terms of an amplifier providing its own input, general discussion, circuit diagrams, etc.
  B. Laboratory: 4 hours
    1. Phase shift oscillator
      a. Frequency range (Lissajous patterns)
      b. Method of feedback
      c. Loading effect
    2. Same for tuned circuit oscillators (Hartley and Colpitts)

IV. Modulation and Detection
  A. Class: 2 hours
    1. Qualitative discussion of AM and FM modulation and detection. Introduce transmitters and receivers

- B. Laboratory: 8 hours
  - 1. (FM) Diode modulator
    - a. Frequency shift with a varying D-C input
    - b. Waveform analysis with an audio signal input
  - 2. (FM) Ratio detector
    - a. Manually vary CW input and record output voltages
    - b. Waveform analysis with input from diode modulator
  - 3. (AM) Pentagrid mixer having a local oscillator and a fixed audio note input
    - a. Waveform analysis including overmodulation
    - b. Frequency analysis of output signals
  - 4. (AM) Diode detector
    - a. Waveform analysis with CW input
    - b. Waveform analysis with input from mixer

- V. Multivibrators and Trigger Circuits
  - A. Class: 2 hours
    - 1. Discussion of the rectangular pulse and methods for generating it. Introduction to triggering circuits and the synchronization of astable, bistable, and monostable multivibrator circuits
  - B. Laboratory: 8 hours
    - 1. Astable multivibrator
      - a. Biasing and feedback networks
      - b. Effect upon output waveform as circuit parameters are varied
    - 2. Bistable and monostable multivibrators
      - a. Biasing and feedback networks
      - b. Manually trigger circuits by grounding base or grids
    - 3. Unijunction trigger oscillator
      - a. Biasing and feedback networks
      - b. Study of the trigger waveform and the synchronization of the above multivibrators
    - 4. Schmitt trigger circuit
      - a. Biasing and signal requirements
      - b. Synchronization of the above multivibrators

- VI. Gating Circuits
  - A. Class: 1 hour
    - 1. Discussion of gating principles and techniques along with an introduction to the basic logic circuits AND, OR, NAND, and NOR
  - B. Laboratory: 4 hours
    - 1. Diode logic circuits (AND, OR, NAND, and NOR)
      - a. Study of circuits and logic with the use of a D-C voltmeter and a manual setting device
      - b. Connect together logic circuits in the laboratory

- VII. Sweep Circuits
  - A. Class: 1 hour
    - 1. Qualitative discussion of time base measurement along with the ramp waveform and sweep circuits
  - B. Laboratory: 4 hours
    - 1. Neon-tube relaxation oscillator
      - a. Study of ramp waveform, time base, amplitude, linearity, etc.
      - b. Effect upon waveform as circuit parameters are varied
    - 2. Same for a bootstrap oscillator
    - 3. Same for a Miller-type sweep circuit

- VIII. Systems
  - A. Class: 2 hours
    - 1. A qualitative study of electronic systems using both the block diagrams and the circuit schematics
  - B. Laboratory: 8 hours
    - 1. Study of electronic systems in the laboratory, such as the oscilloscope, radio and TV receivers, etc. Students should trace circuits, identify stages of operation, and study associated waveforms

SOME SUGGESTED TEXTS AND REFERENCES

The success of this course is dependent upon the instructor's ingenuity in preparing laboratory materials and related instructional supplements. No particular textbook is available for this laboratory emphasized course; however, the student should be encouraged to use the reference library.

ELECTRONICS I

(Resistive Electronic Circuits)

HOURS REQUIRED

Class - 3; Laboratory - 4; Credit - 4.

DESCRIPTION

Electronics I is restricted to resistive circuits in which electronic devices are employed.

The course introduces the volt-ampere characteristics and physics of diodes, transistors, multielement vacuum tubes, and a number of practical resistive circuits using these devices.

INSTRUCTION PROCEDURE

In addition to the presentation of physical and electrical characteristics of electronic devices, this course places emphasis on equivalent circuits for linear operation and on resistive switching techniques, thus introducing a study of amplifiers, logic circuitry and electronic switching.

MAJOR DIVISIONS

	Class Hours	Laboratory Hours
I. Volt-ampere characteristics of Electronic Devices	9	24
II. Physics of Electronic Devices	8	0
III. Linear Audio Amplifiers	8	10
IV. Resistive Diode Circuits	8	10
	33	44

I. Volt-ampere Characteristics of Electronic Devices

A. Class: 9 hours

1. PN junction diode characteristics
2. Zener diode characteristics
3. Tunnel diodes characteristics
4. Vacuum tube diodes
5. Gas diodes

B. Laboratory: 24 hours

1. Volt-ampere characteristics (data gathering and graphical analysis)
   - a. Semiconductor diodes
   - b. Vacuum diodes
   - c. Gas diodes
2. Junction and field affect transistors
   - a. Symbols and circuit configurations
   - b. Transistor parameters
   - c. Common base input-output curve analysis
   - d. Common emitter input-output curve analysis
   - e. Common collector input-output curve analysis
   - f. Input-output resistance analysis for common base, common emitter and common collector configuration
3. The unijunction transistor
   - a. Structure and basic principle of operation
   - b. Symbols
   - c. Input-output characteristics analysis
4. Examination of the physical structure, size and electrical rating of transistors
   - a. Junction transistors
   - b. Field-effect transistors
   - c. Unijunction transistors
5. Experimental data for plotting volt-ampere characteristics of transistors
6. Study of transistors circuits with resistive input-circuits, utilizing D-C driving voltages
7. Analysis of resistive coupled input circuits for holding collector current on and/or off with square wave input voltages
8. Multielement vacuum tubes
   - a. Structure and symbols
   - b. Vacuum tube parameters
   - c. Triode input-output curve analysis
   - d. Tetrode input-output curve analysis

- e. Pentode input-output curve analysis
- f. Interpretation of manufacturer's specifications

9. Examination of physical structure of a number of multielement vacuum tubes
    - a. Triodes
    - b. Tetrodes
    - c. Pentode
    - d. Power amplifiers
    - e. Twin triodes
    - f. Mixers
    - g. Multipurpose tubes
10. Experimental data for plotting volt-ampere characteristics of selected tubes
    - a. Analysis of data for plotting output voltage with controlled D-C input voltage
    - b. Analysis of resistive coupled input circuits for holding plate current on and/or off with square wave input voltages

- II. Physics of Electronic Devices
    - A. Class: 8 hours
        - 1. Semiconductors
            - a. Conduction in a crystalline solid
            - b. Impurities
            - c. Energy-level diagram
            - d. P-N junction diode
            - e. Potential-distribution
        - 2. Conduction through vacuum diodes
            - a. Thermionic emission
            - b. Cathodes and anodes
            - c. Space charge
            - d. The electron volt
            - e. Potential-distribution
        - 3. Gas-filled thermionic diodes
            - a. Ionization
            - b. Deionization
            - c. Potential-distribution
    - B. Laboratory: 0 hours

- III. Linear Audio Amplifiers
    - A. Class: 8 hours
        - 1. Equivalent circuits for A-C operation
            - a. Common base amplifier
            - b. Common emitter amplifier
            - c. Common collector amplifier
            - d. Grounded grid amplifier
            - e. Grounded cathode amplifier
            - f. Grounded plate amplifier
        - 2. Applications of Thevenin's and Norton's Theorems for voltage and current gain analysis
        - 3. Equations for linear operations
            - a. Approximate voltage gain expressions
        - 4. D-C load lines
            - a. Establishing operating points
            - b. Stabilizing operating points
    - B. Laboratory: 10 hours
        - 1. Make mathematical analysis for basic audio amplifier current and/or voltage gains
            - a. Common base amplifiers
            - b. Common collector
            - c. Common emitter
            - d. Grounded grid
            - e. Grounded anode
            - f. Grounded cathode
        - 2. Analyze input-output wave forms
            - a. Phase shift
            - b. Distortion
            - c. Gain measurements

- IV. Resistive Diode Circuits
    - A. Class: 8 hours
        - 1. Single diode circuits
            - a. Current-biased diode circuit
            - b. Single-phase half-wave rectifier circuit
        - 2. Circuit with two or more diodes
            - a. Diode AND circuits, and definitions
            - b. Diode OR circuits and definitions
            - c. General method for solving multiple diode resistance circuits
                - (1) Superposition Theorem
                - (2) Thevenin's Theorem
                - (3) Truth table
    - B. Laboratory: 10 hours
        - 1. Study of diode clipping circuits
        - 2. Study of diode AND and OR circuits using D-C voltage sources
        - 3. Study of single-phase rectifier circuits
        - 4. Study of Zener diodes
        - 5. Study of tunnel diode

SOME SUGGESTED TEXTS AND REFERENCES

Angelo, E. J. Jr., Electronic Circuits, McGraw-Hill Book Company, New York, N. Y., 1964

Gillie, Angelo C., Principles of Electronics, McGraw-Hill Book Company, New York, N. Y., 1962

Kloeffer, Royce Gerald, Electron Tubes, John Wiley & Sons, New York, N. Y., 1966

Lurch, Norman E., Fundamentals of Electronics, John Wiley & Sons, New York, N. Y., 1966

Riddle, R. L. and Ristenbatt, M. P., Transistor Physics and Circuits, Prentice-Hall, Inc., Englewood Cliffs, N. J.

Romanowitz, Alex H., Fundamentals of Semiconductors and Tube Electronics, John Wiley & Sons, New York, N. Y., 1962

Ryder, John, Engineering Electronics, McGraw-Hill Book Company, New York, N. Y., 1967

Thornton, R. D., et al., Handbook of Basic Transistor Circuits and Measurements, John Wiley & Sons, New York, N. Y., 1966

Zines, Ben, Principle of Applied Electronics, John Wiley & Sons, New York, N. Y., 1963

ELECTRONICS II

(Pulse Circuits)

HOURS REQUIRED

Class - 3; Laboratory - 4; Credit - 4.

DESCRIPTION

Electronics II is concerned with the study of electronic circuits in which electronic devices are operated in a switching mode. A number of practical circuits are involved, such as clippers, clampers, pulse formers, multivibrators, blocking oscillators, logic circuits, and sweep circuits.

INSTRUCTION PROCEDURE

A number of pulse circuits are identified by familiar names for particular circuits according to circuit configuration. A greater number are identified by the response attainable rather than by circuit configuration alone. To develop an understanding of both types of circuits it is essential to concentrate during the first part of the course on a single stage circuit. There are three steps in the study of a single stage circuit. First, one studies the circuit behavior for a variety of input circuits and driving voltages. Second, one loads the stage with a variety of circuits to learn the behavior of the one-stage circuit. The third step is to add feedback circuitry to this single stage. The techniques of analysis now known are applicable to all other pulse circuits. Circuits II and Electronics I are prerequisites for Electronics II.

Supplementary notes may be required to support selected texts.

MAJOR DIVISIONS

	Class Hours	Laboratory Hours
I. Diode Switching Circuits	4	0
II. Input Circuits for Grounded Emitter	4	6
III. Output Circuits for Grounded Emitter	4	6
IV. Dual-transistor Pulse Circuits	6	8
V. Triggering, Synchronizing and Gating Techniques	4	8
VI. Logic Circuitry	3	4
VII. Special Switching Devices and Circuits	4	4
VIII. Sweep Circuits and Special Effect of Feedback	4	8
	33	44

I. Diode Switching Circuits
- A. Class: 4 hours
    1. Nonreactive
    2. Resistance switching in R-C circuits
    3. Clamping circuits
- B. Laboratory: 0 hours

II. Input Circuits for Grounded Emitter (Transistors, Common Emitter)
- A. Class: 4 hours
    1. Significant characteristics of transistors for switching mode of operation
        - a. Input resistance
        - b. Minimum base current required for saturation
        - c. D-C voltage and current ratings
        - d. Current transfer function
    2. Square wave testing of transistor characteristics
    3. Input circuits
        - a. Series resistor
        - b. R-C input circuits
        - c. Modified R-C input circuits
        - d. Direct coupled input circuits
- B. Laboratory: 6 hours
    1. Square wave testing of transistor
    2. Study and evaluation of R-C input circuits
        - a. NPN transistors
        - b. PNP transistors

III. Output Circuits for Grounded Emitter
- A. Class: 4 hours
    1. Capacitive loading (pulsed input voltage)

      - a. Equivalent circuit and calculations for switching mode of transistor operation
      - b. A method of generating sweep voltage
    - 2. R-C loading
      - a. Equivalent circuit and calculations
      - b. Modified R-C loading with resistance switching
    - 3. Resistance loading with resistance switching
    - 4. Inductance loading
  - B. Laboratory: 6 hours
    - 1. Study and calculations with capacitance loading
    - 2. Loading with linear R-C circuits and switching R-C circuits
    - 3. Inductance loading

IV. Dual-transistor Pulse Circuits
  - A. Class: 6 hours
    - 1. Basic circuitry for the major types of dual-transistor pulse circuits (NPN's or PNP's)
      - a. Astable multivibrator
      - b. Monostable multivibrator
      - c. Bistable multivibrator
      - d. Schmitt trigger circuit
    - 2. Techniques of preceding sections that are applicable to a solution and evaluation of waveforms for these circuits
    - 3. The astable multivibrator (common emitter configuration)
      - a. Problems of saturation (fall-out)
      - b. Study of waveforms with zero biasing
      - c. Need for biasing the circuit
      - d. Methods of frequency control
      - e. Methods of improving waveforms
      - f. Complete evaluation of voltage waveforms
    - 4. The bistable multivibrator
      - a. Possible circuits
      - b. Factors that determine bistable mode of operation
      - c. Calculation of significant quantities for either bistable state
    - 5. The monostable multivibrator
      - a. Possible circuits
      - b. Factors that determine monostable mode of operation
      - c. Calculations for the circuit
    - 6. The Schmitt trigger circuit
      - a. The typical circuit
      - b. Method of operation and control
      - c. Calculation of significant quantities
      - d. A voltage-level discriminator
      - e. The Schmitt circuit using complementary transistors
  - B. Laboratory: 8 hours
    - 1. Study of astable circuit (NPN's or PNP's)
    - 2. Study of monostable circuit (NPN's or PNP's)
    - 3. Study of Schmitt trigger circuit (NPN's or PNP's)
    - 4. Design of a bistable circuit

V. Triggering, Synchronizing and Gating Techniques
  - A. Class: 4 hours
    - 1. Methods of triggering bistable multivibrators
      - a. From a single source
      - b. From two or more sources
      - c. Direct coupling using diodes
      - d. R-C coupling using diodes
      - e. R-C coupling without diodes
      - f. Resistance coupling without diodes
    - 2. Places in the bistable circuit to apply trigger pulses
    - 3. Triggering of monostable circuits
    - 4. Synchronizing of astable circuits
    - 5. Synchronizing of clocking oscillators
    - 6. The monostable circuit as a gate generator
  - B. Laboratory: 8 hours
    - 1. Triggering of bistable circuits
    - 2. Synchronizing of astable circuits

VI. Logic Circuitry
  - A. Class: 3 hours
    - 1. AND circuits
    - 2. OR circuits
    - 3. NOT circuits
    - 4. NAND circuits
    - 5. NOR circuits

6. Application for bistable multivibrator in logic circuits
    a. Storage element
    b. Counting
    c. Shift register

B. Laboratory: 4 hours
  1. Design of AND circuit
  2. Design of OR circuit
  3. Cascade four bistable multivibrators for BCD representation
  4. Interconnecting bistable circuits to form a double-rank register with left and right shifts

VII. Special Switching Devices and Circuits
  A. Class: 4 hours
    1. Complementary transistor circuits
      a. Direct coupled circuits with npn-pnp transistors
      b. R-C coupled circuits with npn-pnp transistors
      c. Pulse-forming circuits with npn-pnp transistors
      d. Gating circuits with npn-pnp transistors
    2. Zenor diodes
      a. Properties
      b. Zenor diode pulse circuits
    3. Unijunction transistors
      a. Properties
      b. Unijunction transistor pulse circuits
    4. Silicon controlled rectifiers
      a. Properties
      b. Silicon controlled rectifier for switching and power control circuits
    5. Tunnel diodes
      a. Properties
      b. Tunnel diode switching and oscillator circuits
  B. Laboratory: 4 hours
    1. Schmitt trigger circuit (using complementary transistors)
    2. Two-stage direct coupled (using complementary transistors)

VIII. Sweep Circuits and Special Effects of Feedback
  A. Class: 4 hours
    1. Sweep circuits without feedback
      a. With transistors
      b. With unijunction transistor
      c. With silicon-controlled rectifiers
      d. Equivalent circuits and calculations
    2. Free-running vs. synchronized sweeps
    3. Sweep circuits with feedback
      a. Miller sweep circuit
      b. Bootstrap sweep circuit
      c. Equivalent circuits and calculations
    4. Recovery time and circuit techniques for reducing recovery time in feedback circuits
    5. Blocking oscillator and pulse transformers
  B. Laboratory: 8 hours
    1. Study of sweep circuits without feedback
    2. Study of Miller and Bootstrap sweep circuits
    3. Practical significance of recovery time and circuitry techniques for improvement

SOME SUGGESTED TEXTS AND REFERENCES

Babb, Daniel S., Pulse Circuit Switching and Shaping, Prentice-Hall, Englewood Cliffs, New Jersey, 1964

Doyle, Jim, Pulse Fundamentals, Prentice-Hall, Englewood Cliffs, New Jersey, 1963

Harris, J. N., Gray, R. E., and Searle, C. L., Digital Transistor Circuits, John Wiley & Sons, New York, N. Y., 1966

Millmann, Jacob and Taub, Herbert, Pulse Digital and Switching Waveforms, McGraw-Hill, New York, N. Y., 1965

Pettit, J. M., Electronic Switching, Timing and Pulse Circuits, McGraw-Hill, New York, N. Y., 1959

Stanton, William A., Pulse Technology, John Wiley & Sons, New York, N. Y., 1964

Stiltz, H. L., Aerospace Telemetry, Prentice-Hall, Englewood Cliffs, New Jersey, 1961

Strauss, L., Wave Generation and Shaping, McGraw-Hill, New York, N. Y., 1960

ELECTRONICS III

(Advanced Electronics)

HOURS REQUIRED

Class - 4; Laboratory - 4; Credit - 5.

DESCRIPTION

Advanced Electronics is the study of electronic circuits in which vacuum tubes and transistors are operated in the linear region of their volt-ampere characteristics such that linear equivalent circuits can be applied in the analysis. The course covers power supplies, amplifiers, feedback circuits, oscillators, modulation systems and detectors.

INSTRUCTION PROCEDURE

There are two general methods of approach in studying the circuits of this course. One method concentrates on equivalent circuits and the solution of these circuits. The other method concentrates on graphical analysis. Sometimes one method is desirable over the other. In other cases, such as piecewise solutions, both should be used.

Supplementary notes may be required to support selected texts.

MAJOR DIVISIONS

		Class Hours	Laboratory Hours
I.	Power Supplies	5	4
II.	Transistor Amplifiers	8	10
III.	Vacuum-Tube Amplifiers	3	2
IV.	Audio Frequency Power Amplifiers	6	4
V.	Frequency Response of Amplifiers	6	8
VI.	Feedback and Oscillators	8	8
VII.	Modulation and Demodulation	8	8
		44	44

I. Power Supplies
  A. Class: 5 hours
    1. Rectifier circuits
      a. Single phase half-wave
      b. Single phase full-wave
      c. Single phase bridge circuits
    2. Filters
      a. R-C filters
      b. L-R filters
      c. L-C filters
      d. Multiple sections
    3. Regulated power supplies
      a. Using gas-filled tubes
      b. Using amplifying devices with feedback
  B. Laboratory: 4 hours
    1. Study of single-phase rectifier circuits without filtering
      a. Analysis of waveforms
      b. Measurement of ripple factor
      c. Measurement of D-C components
    2. Design of power supplies with filters
      a. With R-C filters
      b. With L-R filters
      c. With L-C filters
      d. With multiple sections of filters
    3. Design and study of regulated power supplies

II. Transistor Amplifiers
  A. Class: 8 hours
    1. Linear equivalent circuit analysis
    2. Graphical analysis
    3. Power relationships
    4. Quiescent operating points
      a. Choice of operating point
      b. Problems
      c. Stabilization of operating points
    5. Load coupling circuits
      a. R-C coupling
      b. Transformer coupling
      c. Inductive loads
  B. Laboratory: 10 hours
    1. Study of the basic transistor amplifier
      a. Load lines
      b. Quiescent operating points
      c. Power relations

        - d. Determination of transistor parameters
        - e. Stabilization techniques
        - f. Voltage and current gains
    - 2. Study of transformer coupled loads
        - a. Impedance transformation
        - b. Quiescent point determinations
        - c. Temperature compensation
    - 3. Study of R-C coupled loads
    - 4. Study of inductive loads

III. Vacuum Tube Amplifiers
- A. Class: 3 hours
    - 1. Linear equivalent circuit analysis
    - 2. Graphical analysis
    - 3. Gain and amplification in decibels
    - 4. Load coupling circuits
        - a. Transformer coupling
        - b. R-C coupling
        - c. Inductive loads
    - 5. Power relations
    - 6. Cathode-resistor bias
- B. Laboratory: 2 hours
    - 1. Study of a basic amplifier
        - a. Voltage gain
        - b. Quiescent operating points
        - c. Range of operation
        - d. Harmonic components
        - e. Power relations (A-C and D-C)
    - 2. Study of an amplifier with transformer coupled to a resistive load
        - a. Impedance transformation
        - b. A-C load line
        - c. Voltage gain
    - 3. Study of amplifier with capacitance and resistance-capacitance loading
        - a. Mid-band studies only
        - b. Range of capacitance values to give maximum voltage gain
        - c. A-C load lines and the equation for this load line
        - d. Voltage gains verified with calculations
    - 4. Study of amplifier with inductance leading
        - a. Voltage gain
        - b. Load lines
        - c. Voltage gains verified with calculations

IV. Audio-Frequency Power Amplifiers
- A. Class: 6 hours
    - 1. Class A transistor power amplifiers
    - 2. Push-pull amplifiers
        - a. Class B
        - b. Class B using complementary transistors
        - c. Class A
        - d. Class AB
- B. Laboratory: 4 hours
    - 1. Study of class A transistor power amplifiers
        - a. Temperature limitations
        - b. Operating path limitations
        - c. Maximum power output
        - d. Design of a power amplifier
    - 2. Study of push-pull class B amplifiers with transistors
        - a. Design of the circuit
        - b. Analysis of waveforms
        - c. Harmonic contents
        - d. Power capabilities
    - 3. Study of push-pull class B transistorized amplifiers using complementary transistors
        - a. Design of the circuit
        - b. Analysis of waveforms
        - c. Power capabilities

V. Frequency Response of Amplifiers
- A. Class: 6 hours
    - 1. Single-stage amplifiers
        - a. Transistor amplifier at high frequencies
        - b. Transistor amplifier at low frequencies
        - c. Pentode amplifier
        - d. Triode amplifier
        - e. The emitter follower at high frequencies
        - f. The cathode follower at high frequencies
        - g. Gain vs. band width
    - 2. Cascaded amplifiers
        - a. R-C coupled transistor amplifiers
        - b. R-C coupled vacuum tube amplifiers
            - (1) Triodes
            - (2) Pentodes
        - c. Pole-zero studies
    - 3. Tuned amplifiers
        - a. Single-tuned transistor amplifiers

        - b. Single-tuned vacuum tube amplifiers
        - c. Double-tuned amplifiers
        - d. Cascaded tuned amplifiers
    - 4. Frequency compensation in R-C coupled amplifiers
    - 5. Tuned amplifiers
- B. Laboratory: 8 hours
    - 1. Frequency response studies
        - a. For selected circuits (tubes and transistors)
        - b. Data methods for frequency response curves
        - c. Half-power points
        - d. Band width
        - e. Techniques of expanding band width
        - f. "Corner plot" techniques of plotting
        - g. Tuned amplifiers

VI. Feedback and Oscillators

- A. Class: 8 hours
    - 1. Feedback circuits
        - a. Voltage and current feedback
        - b. General feedback equation
        - c. Emitter follower
        - d. Cathode follower
        - e. Collector-to-base feedback
        - f. Plate-to-grid feedback
    - 2. Effects of feedback on amplifier characteristics
        - a. Gain
        - b. Band width
        - c. Noise
        - d. Distortion
        - e. Stability (Nyquist criteria)
        - f. Output impedance
    - 3. Oscillators (criteria for oscillations)
        - a. Negative resistance requirement
        - b. Barkheusen criteria
        - c. Equivalent circuit methods
    - 4. Oscillators (circuits)
        - a. Tuned circuit oscillators
            - (1) Tuned grid
            - (2) Tuned plate
            - (3) Hartley
            - (4) Colpitts
            - (5) Crystal oscillator
        - b. R-C oscillator
            - (1) Wein bridge circuit
            - (2) Phase shift circuit
        - c. The tunnel diode
- B. Laboratory: 8 hours
    - 1. Study of feedback circuits
        - a. Effect on gain
        - b. Effect on output impedance and admittance
        - c. Effect on distortion
        - d. Effect on stability
    - 2. Study of tuned oscillator circuits
        - a. For selected circuits
        - b. Design for specified frequency of operation
        - c. Band width requirements
    - 3. Study of R-C oscillators
        - a. Design of Wein bridge oscillator
        - b. Design of phase-shift oscillator
        - c. Laboratory checks on performance

VII. Modulation and Demodulation

- A. Class: 8 hours
    - 1. Types of modulation
        - a. Amplitude (AM)
        - b. Frequency modulation (FM)
        - c. Pulse-code-modulation (PCM)
    - 2. Amplitude modulation
        - a. Methods of production
            - (1) Diode
            - (2) Grid modulated tube
            - (3) Plate modulated tube
        - b. Equations showing frequency components
        - c. Circuit analysis
    - 3. Amplitude demodulation
        - a. The diode detector circuit
        - b. Other methods of detection
        - c. Filtering requirements
    - 4. Frequency modulation
        - a. Methods of production
            - (1) Reactance tube modulator
            - (2) Armstrong method
        - b. Equations showing frequency components
            - (1) Spectrum display
            - (2) Side frequencies
    - 5. Frequency modulation detectors
        - a. Discrimination and phasor diagram
        - b. Ratio detectors and phasor diagrams
        - c. Other circuits as modifications of (a) and (b)

    6. Pulse-code modulation
        a. Types
        b. Circuitry techniques

B. Laboratory: 8 hours
    1. Study of amplitude modulation with diodes
    2. Study of amplitude modulation with transistors
    3. Study of amplitude modulation with tubes (plate modulation recommended)
    4. Study of discriminators
    5. Study of ratio detectors
    6. Study of reactance-tube modulators

SOME SUGGESTED TEXTS AND REFERENCES

Alley, C. L. and Azwood, K. W., Electronic Engineering, John Wiley & Sons, Inc., New York, N. Y., 1962

Angelo, E. J., Electronic Circuits, McGraw-Hill, New York, N. Y., 1964

Corning, John J., Transistor Circuit Analysis and Design, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1965

Cutler, Philip S., Semiconductor Circuit Analysis, McGraw-Hill, New York, N. Y. 1964

Fitzgerald, A. E. and Higginbutham, D. E., Electrical and Electronic Engineering Fundamentals, McGraw-Hill, New York, N. Y., 1964

Gillie, Angelo C., Principles of Electron Devices, McGraw-Hill, New York, N. Y. 1962

Joyce, M. V. and Clarke, K. K., Transistor Circuit Analysis, Inc. Reading, Massachusetts, 1961

Reich, H. J., Functional Circuits and Oscillators, D. Van Nostrand Company, Inc., New York, N. Y., 1961

Ryder, John, Engineering Electronics, McGraw-Hill, New York, N. Y., 1967

Seidman, A. H., Semiconductor Fundamentals Devices and Circuits, John Wiley & Sons, New York, N. Y., 1963

Texas Instruments, Inc. (staff), Transistor Circuit Design, McGraw-Hill, New York, N. Y., 1963

Thornton, R. D., Searle, C. L., Pederson, D. O., Adler, R. T., and Angelo, E. J., Jr., Multistage Transistor Circuits

Zimmerman, H. J. and Mason, S. J., Electronic Circuit Theory, John Wiley & Sons, Inc., New York, N. Y., 1960

CIRCUITS I

(Resistive Circuits)

HOURS REQUIRED

Class - 4; Laboratory - 2; Credit - 3.

DESCRIPTION

Circuits I is restricted to a study of resistive circuits in which the source voltage can be time-varying as well as D-C sources. The first portions of the course introduce the physics of electricity, along with units, definitions, symbols, and notations for electrical quantities. The major portion of the course is a study of circuit properties and their applications to significant circuit configurations.

INSTRUCTION PROCEDURE

Inspection of the course outlines for the three circuits courses of this curriculum reveals no reference to D-C circuits and A-C circuits, which would imply a study of circuits with D-C voltage sources and with sinusoidal voltage sources. Modern circuit analysis problems require a more extensive treatment to include electronic switching techniques.

This first course in circuits, restricted to resistive circuits, requires only a knowledge of algebra and trigonometry. A study of resistive circuits will prepare the student for Electronics I, also restricted to resistive circuits that employ electronic devices. Circuits with capacitors and/or inductors are studied for the first time in Circuits II and Electronics III.

MAJOR DIVISIONS

		Class Hours	Laboratory Hours
I.	Concepts of Electricity	4	2
II.	The Electric Circuit	2	2
III.	Basic Circuit Nomenclature	2	0
IV.	Fundamental Circuit Properties	5	4
V.	Basic Circuit Configurations	5	4
VI.	Network Equations	6	2
VII.	Equivalent Circuits	8	2
VIII.	Resistive Network Analysis	7	4
IX.	Power and Energy	5	2
		44	22

I. Concepts of Electricity
  A. Class: 4 hours
    1. Atomic structure
      a. Molecules
      b. Atoms and major components
      c. Free electrons
    2. Electric charge
      a. Static properties
      b. Potential and units
    3. Charges in motion
      a. Relationship to potential
      b. Energy of moving charges
      c. Current and units
    4. Conduction properties of materials
      a. Conductors
      b. Insulators
      c. Semi-conductors
    5. Sources
      a. Energy conversion
        (1) Cell
        (2) Generator
        (3) Thermocouple
        (4) Friction
        (5) Piezoelectric
        (6) Photoelectric
      b. Constant value
      c. Time-varying
        (1) Types
          (a) Sinusoidal
          (b) Ramp
          (c) Pulse
          (d) Exponential
          (e) Complex
        (2) Waveform graphing
        (3) Addition
          (a) Instantaneous values
        (4) Frequency, period, wave length
        (5) Values
          (a) Instantaneous

- (b) Peak
- (c) Average
- (d) R.M.S.
- 6. Applications and problems
- B. Laboratory: 2 hours
  - 1. Introduction to laboratory facilities and procedures for the course
  - 2. Waveform graphing and measuring of peak, average and RMS values of time-varying signals. Compare measured with computed values.

II. The Electric Circuit

- A. Class: 2 hours
  - 1. Circuit elements
    - a. Passive
      - (1) Resistance and units
      - (2) Conductance and units
      - (3) Reactance - Phase
    - b. Active
      - (1) Independent sources
        - (a) Voltage
        - (b) Current
        - (c) Live vs. dead
      - (2) Dependent sources
  - 2. Physical circuits and models
    - a. Approximations
- B. Laboratory: 2 hours
  - 1. Measurement of variation of physical devices from their model, i.e., resistance and capacitance in coil.

III. Basic Circuit Nomenclature

- A. Class: 2 hours
  - 1. Notation
    - a. Double subscript
    - b. Single subscript
  - 2. Reference currents and voltages
    - a. Free choice
    - b. Current
    - c. Voltage
  - 3. Volt-ampere graphs
    - a. Slope
  - 4. Applications and problems
- B. Laboratory: 0 hours

IV. Fundamental Circuit Properties

- A. Class: 5 hours
  - 1. Ohm's Law
    - a. Solve for V
    - b. Solve for I
    - c. Solve for R
  - 2. Kirchhoff's current law
  - 3. Kirchhoff's voltage law
  - 4. Applications and problems
- B. Laboratory: 4 hours
  - 1. Study of Ohm's Law
  - 2. Study of Kirchhoff's current law
  - 3. Study of Kirchhoff's voltage law
  - 4. Plotting of volt-ampere graphs

V. Basic Circuit Configurations

- A. Class: 5 hours
  - 1. Series circuits
  - 2. Parallel circuits
  - 3. Series-parallel circuits
  - 4. Applications and problems
- B. Laboratory: 4 hours
  - 1. Study of three basic circuit configurations employing Kirchhoff's laws and Ohm's Law

VI. Network Equations

- A. Class: 6 hours
  - 1. Node equations
  - 2. Loop equations
  - 3. Mesh equations
  - 4. Applications and problems
- B. Laboratory: 2 hours
  - 1. Network measurements and network solutions by network equations

VII. Equivalent Circuits

- A. Class: 8 hours
  - 1. Superposition Theorem
  - 2. Thevenin's Theorem
  - 3. Norton's Theorem
  - 4. Circuit conversions
  - 5. Applications and problems
- B. Laboratory: 2 hours
  - 1. Comparative measurements in given circuits and application of superposition, Thevenin's, and Norton's Theorems

VIII. Resistive Network Analysis

- A. Class: 7 hours
  - 1. T-circuits
  - 2. - circuits
  - 3. - T conversions
  - 4. Bridge circuits
  - 5. Delta circuits
  - 6. Wye circuits
  - 7. Delta-wye conversions
  - 8. Single source networks
  - 9. Multiple source networks
  - 10. Networks with dependent sources
  - 11. Applications and problems

B. Laboratory: 4 hours
   1. Study of and T circuits
   2. Study of bridge circuits
   3. Study of and Y three-phase balanced systems
   4. Study of multiple source networks

IX. Power and Energy
   A. Class: 5 hours
      1. Definitions and derivations
      2. Units
      3. Methods for solution
      4. Applications and problems
   B. Laboratory: 2 hours
      1. Measurement of A-C and D-C power and comparison with calculated values

SOME SUGGESTED TEXTS AND REFERENCES

Anderson, C. J., Santanelli, A., and Kulis, F. R., Direct Current Circuits and Measurement, Prentice-Hall, Englewood Cliffs, New Jersey, 1966

Babb, D. S., Resistive Circuits, International Textbook Co., Scranton, Pa., 1968, (Tentative)

Fishe, K. A., and Harter, J. H., Direct Current Circuit Analysis Through Experimentation, Technical Education Press, Seal Beach, California, 1966

Jackson, H. W., Introduction to Electric Circuits, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1959

Riaz, M., Electrical Engineering Laboratory Manual, McGraw-Hill, New York, 1965.

Slurzberg, M., and Osterheld, W., Essentials of Electricity-Electronics, 3d ed., McGraw-Hill, New York, 1965

Timbie, W. H., (assisted by Kuske, A.), Elements of Electricity, John Wiley & Sons, Inc., New York, N. Y.

Timbie, W. H. and Ricker, F. J., Basic Electricity for Communications, John Wiley & Sons, Inc., New York, N. Y.

Tinnell, R. W., Experiments in Electricity-A.C., McGraw-Hill, New York, 1966.

Tinnell, R. W., Experiments in Electricity-D.C., McGraw-Hill, New York, 1966.

(See Circuits III for other references.)

CIRCUITS II

(Single - Time - Constant Circuits)

HOURS REQUIRED

Class - 4; Laboratory - 4; Credit - 4.

DESCRIPTION

Circuits II is restricted to a study of single-time-constant circuits. In other words, R-C and R-L circuits but not R-L-C and L-C circuits. Approximately the first half of the course is a study of basic switching circuitry and circuits with square-wave and step voltages as sources. The second half of the course concentrates on sinusoidal voltages as the voltage sources.

INSTRUCTION PROCEDURE

Introduction of capacitors and inductors into a circuit requires a knowledge of calculus. Restricting the circuits to the single-time-constant type of circuit keeps the calculus requirement to a minimum and, at the same time provides an abundance of circuits that require analysis. Calculus is included in Technical Mathematics II, but not at the beginning of that course. In the early part of this course it is possible to use mathematical expressions that are a result of calculus derivations without requiring the students to perform these early derivations.

MAJOR DIVISIONS

	Class Hours	Laboratory Hours
I. Properties of Capacitance and Inductance	4	0
II. R-C, R-L Circuits	8	8
III. Resistive Switching in R-C Circuits	12	12
IV. Rectangular Input Voltage Applied to Constant Parameter Circuits	4	6
V. Sinusoidal Voltages Applied to Constant Parameter Circuits	12	12
VI. Transformers	4	6
	44	44

I. Properties of Capacitance and Inductance
  A. Class: 4 hours
    1. Definition of L and C
    2. Mathematical concepts describing properties of L and C
    3. Series, parallel, and series-parallel combinations

  B. Laboratory: 0 hours

II. R-C and R-L Circuits
  A. Class: 8 hours
    1. The exponential response
    2. Time constants
      a. R-C circuits
      b. R-L circuits
      c. R-C and R-L circuits that reduce to circuits of single resistance and single capacitance or inductance
      d. Identification of single-time-constant circuits
    3. Graphs of voltages and currents in single-time-constant circuits
    4. Calculation of initial and asymptotic values of voltage and current
    5. General equation for an exponential quantity in terms of initial value, asymptotic value and circuit time constant
    6. Use of slide rule in the evaluation of exponentials
    7. Problems and applications

  B. Laboratory: 8 hours
    1. Study of response of R-L and R-C circuits to square wave input
      a. Resistance voltage waveform
      b. L or C voltage waveform
      c. Time constant measurement

III. Resistance Switching in R-C Circuits (Single-time-constant circuits only)
  A. Class: 12 hours
    1. Concept of resistance switching using diodes
    2. Generalized resistance switching circuit
    3. Area ratio concepts for resistance voltage

      a. Rectangular waveform as the input voltage
      b. Sinusoidal voltage input (for large capacitance only)
    4. Definition of rise time and typical problems
    5. Diode clamping circuits
      a. Clamping to a reference voltage
      b. Three methods of biasing the circuit
  B. Laboratory: 12 hours
    1. Study of R-C circuits with resistance switching
      a. Rectangular input voltage
      b. Sinusoidal input voltage (large C only)
    2. Measurement of unknown resistance using the techniques of this section
    3. Effects of output resistance (can be multi-valued) of voltage sources
    4. Measurements of rise time
    5. Study of diode clamping circuits

IV. Rectangular Input Voltage Applied to Constant Parameter Circuits
  A. Class: 4 hours
    1. Linear R-C series circuits treated as a special case of resistance switching where resistance ratio is unity
    2. Complete analysis of R-C and R-L networks (evaluation of all voltages and currents)
  B. Laboratory: 6 hours
    1. Supervised study and problem solving

V. Sinusoidal Voltage Applied to Constant Parameter Circuits
  A. Class: 12 hours
    1. Inductive and capacitive reactance and impedance
    2. Instantaneous values
    3. Phasor quantities
      a. Rectangular form
      b. Polar form
    4. Complex numbers as applied to circuit analysis
    5. The j operator
    6. Writing complex numbers and phasor representation
    7. Use of slide rule for polar-rectangular conversion
    8. Addition and subtraction of phasors
    9. Multiplication of phasors (rectangular and polar form)
    10. The complex conjugate
      a. Definition
      b. Reciprocal of complex quantities
    11. Division of phasors (rectangular and polar form)
    12. Rotating phasors and complex number rotation
    13. Roots of complex numbers and phasor notation
    14. Phasor addition of two or more sinusoids that are not all in phase
      a. Resultant phase angle
      b. Magnitude of resultant
    15. Multiplication of a sinusoidal voltage by a sinusoidal current (same frequencies)
      a. Phase angle
      b. Lead and lag
      c. Significance of j term of resultant
      d. Significance of real term of resultant
      e. Significance of the resultant magnitude
  B. Laboratory: 12 hours
    1. Student drill problems
    2. Study of electrical quantities for resistors, capacitors, and inductors in circuit with sinusoidal input
    3. Techniques of use of instruments in measurements

VI. Transformers
  A. Class: 4 hours
    1. Mutual inductance
    2. Turns ratio
    3. Voltage and current ratios
    4. Reflected impedance
    5. Transformer polarization
  B. Laboratory: 6 hours
    1. Use of two coils that can be moved with respect to one another (study of mutual inductance)
    2. Study of power transformers
      a. Volt-ampere ratings
      b. Ampere-turns relationship
      c. Autotransformers
      d. NARIACS

SOME SUGGESTED TEXTS AND REFERENCES

Refer to Circuits III for list of suggested texts and references.

CIRCUITS III

(Network Analysis)

HOURS REQUIRED

Class - 3; Laboratory - 4; Credit - 4.

DESCRIPTION

Circuits III is a study of networks that will not reduce to simple single-time constant circuits. Only stead-state solutions are considered, enabling the use of the S-plane in circuit analysis.

This course is a prerequisite for the Circuits IV elective course.

INSTRUCTION PROCEDURE

The outline for this third circuits course may appear heavily loaded with material. On the other hand, the studies of the preceding two circuits courses should permit a comparatively more rapid pace through much of the material of the course. The major divisions I through VI are of greatest importance. Some work on magnetic coupling is certainly desirable. In some cases it may be desirable to delete three-phase circuits and include some work with transient analysis.

MAJOR DIVISIONS

		Class Hours	Laboratory Hours
I.	Series Circuits	4	8
II.	Parallel Circuits	4	8
III.	Series-parallel Circuits	6	6
IV.	S-plane	4	0
V.	Network Equations Using the S-operator	5	4
VI.	Circuit Theorems and Applications using the S-operator	4	6
VII.	Magnetic Coupling	3	6
VIII.	Three-phase Circuits	3	6
		33	44

I. Series Circuit
  A. Class: 4 hours
    1. R-C series circuit
      a. Input impedance
      b. Voltage and current phasor diagrams
      c. Locus diagrams
      d. Response as a function of frequency
        (1) Resistance voltage as output
        (2) Capacitor voltage as output
      e. Response as a function of capacitance
      f. Power and power-factor
    2. R-L series circuit
      a. Input impedance
      b. Voltage and current phasor diagrams
      c. Locus diagrams
      d. Response as a function of frequency
        (1) Resistance voltage as output
        (2) Inductor voltage as output
      e. Response as a function of inductance
      f. Power and power-factor
      g. The Q of a coil
    3. R-L-C series circuit
      a. Input impedance
      b. Voltage and current phasor diagrams
      c. Resonance
        (1) Natural resonant frequency
        (2) Phase resonance
        (3) Amplitude resonance
      d. Voltage magnitudes as a function of frequency; of inductance; of capacitance
      e. Current magnitude as a function of frequency for a number of L/C ratios with LC = constant
      f. Power and power-factor
  B. Laboratory: 8 hours
    1. Using the voltmeter-ammeter-wattmeter method, determine magnitudes of resistance and reactance of an unknown impedance at a specified frequency.

2. Using a voltmeter, an ammeter, and a known resistance, determine the resistance and reactance of an unknown impedance.
3. Procedures to determine whether a reactance is inductive or capacitive.
4. Study of R-L-C series circuits with (a) frequency variable; (b) capacitance variable; (c) inductance variable.
5. Study of R-L-C series circuit with frequency variable, constant LC, but with different L/C ratios

II. Parallel Circuits
  A. Class: 4 hours
    1. R-C parallel circuit
      a. Input impedance
      b. Concept of admittance
      c. Current and voltage phasor diagrams
      d. Locus diagrams
      e. Current as a function of frequency
    2. R-L parallel circuit
      a. Input impedance
      b. Input admittance
      c. Current and voltage phasor
      d. Locus diagrams
      e. Current as a function of frequency
    3. L-C parallel circuit
      a. Input impedance as a function of frequency (impedance plotted as a complex number)
      b. Current and voltage phasor diagrams
      c. Resonance
    4. R-L-C parallel circuit
      a. Voltage, current and power calculations
      b. Resonance
      c. Damped oscillations
    5. R-L series circuit in parallel with an R-C series circuit
      a. Voltage, current and power calculations
      b. Input impedance and admittance
      c. Condition for phase resonance
      d. Locus diagrams
      e. Phasor diagrams
    6. Power and power-factor of parallel circuits
  B. Laboratory: 8 hours
    1. Study of R-C parallel circuits
    2. Study of R-L parallel circuits
    3. Study of R-L-C parallel circuits
    4. Study of a general parallel circuit (R-L series circuit in parallel with R-C series circuit)
    5. Impedance and admittance measurements for parallel circuits

III. Series - Parallel Circuits
  A. Class: 6 hours
    1. Complete solution (all voltages and currents)
      a. Simplification by applying Ohm's Law and Kirchhoff's Laws
      b. Input impedance
      c. Phasor diagrams
  B. Laboratory: 6 hours
    1. Study of series-parallel circuits
      a. Measurements of all voltages and currents
      b. Application of Kirchhoff's Laws and Ohm's Law
      c. Power measurements
      d. Input impedance and input admittance
    2. Frequency response of L-C circuits

IV. The S-plane
  A. Class: 4 hours
    1. Definition and relationship to $j\omega$
    2. Phasor - S-plane transformations
    3. Poles and zeros
    4. Significance of right-hand and left-hand planes
    5. Significance of zeros on $j\omega$ axis
    6. Applications to series, parallel, and series-parallel circuits
    7. Problems
  B. Laboratory: 0 hours

V. Network Equations with S-operator
  A. Class: 5 hours
    1. Network terminology
      a. Sources
        (1) Independent
        (2) Dependent
      b. Junction
      c. Node
      d. Branch
      e. Loop
      f. Passive elements

- 2. Branch equations
- 3. Loop equations
  - a. Choice of loops
  - b. Standard form
- 4. Node equations
  - a. One independent node
  - b. Two or more independent nodes
  - c. Standard form
- 5. Number of nodes and/or loops
- 6. Elimination of nodes and loops
- 7. Problem solving

B. Laboratory: 4 hours
- 1. Supervised problem solving
- 2. Completing unfinished experiments of preceding sections

VI. Circuit Theorems and Applications with the S-operator

A. Class: 4 hours
- 1. Superposition theorem
- 2. Thevenin's theorem
- 3. Norton's theorem
- 4. Maximum power transfer theorem
- 5. T and equivalence and transformations
  - a. Two-port networks
  - b. Open-circuit and short-circuit tests

B. Laboratory: 6 hours
- 1. The superposition theorem can be studied by connecting a three-terminal network to a three-phase source, or by using a transformer (center tap on secondary) connected to a single-phase source. Make voltage, current and phase measurements in one or more parts of the circuit with
  - a. The complete circuit
  - b. One source voltage removed and terminals at network shorted
  - c. Verify the superposition theorem from experimental measurements
- 2. Thevenin's and Norton's theorems can be studied by connecting a two-terminal network to a single-phase source. At any other two terminals of the network
  - a. Determine experimentally, the Thevenin's or Norton's equivalent circuit
  - b. Connect unknown impedance to these two terminals and make measurements and calculations to verify the theorems
- 3. Determine the equivalent T and π networks of a given two-port network

VII. Magnetic Coupling

A. Class: 3 hours
- 1. Mutual coupling
- 2. Faraday's Law
- 3. Polarity of induced voltages
- 4. Coefficient of coupling
- 5. Close-coupled circuits
  - a. Power transformers
  - b. Transformer equivalent circuits
  - c. Ampere-turn relationships
  - d. Leakage reactances
  - e. Phasor diagrams for transformers
  - f. Problem solving with fictitious generator
  - g. A-F transformers
- 6. Loose-coupled circuits
  - a. R-F transformers
  - b. I-F transformers
  - c. Frequency response and degree of coupling
  - d. Problem solving
    - (1) Complete phasor diagrams
    - (2) Impedance transformations

B. Laboratory: 4 hours
- 1. Study and application of double-tuned I-F transformers (Frequency response)
- 2. Study and application of A-F transformers
  - a. Impedance matching
  - b. Power transfer
  - c. A-F transformers in push-pull audio amplifiers

VIII. Three-phase Circuits

A. Class: 3 hours
- 1. Generation of three-phase voltages
- 2. Load connections

      a. Delta
      b. Wye
   3. Transformer connections
      a. Delta
      b. Wye
      c. Open delta
   4. Vector diagrams of all voltages and currents
      a. Unity power-factor load
      b. Lagging power-factor load
      c. Loading power-factor load
   5. Voltages and current calculations
   6. Equivalent wye and delta circuits
   7. Three-phase power
      a. Definition
      b. Measurements
      c. Calculations
   8. Power factor correction
   9. Single-phase loads on three-phase systems
   10. Distribution systems
B. Laboratory: 8 hours
   1. Connecting single-phase transformers to a three-phase system
      a. Procedure for testing transformers for proper connections
      b. Wye connection
      c. Delta connection
   2. Measurement of power in three-phase systems
      a. One-wattmeter method (balanced load only)
      b. Three-wattmeter method (unbalanced loads)
      c. Two-wattmeter method (unbalanced loads)

SOME SUGGESTED TEXTS AND REFERENCES

Balabanian, N., Fundamentals of Circuit Theory, Allyn and Bacon, Inc., Boston, Massachusetts, 1961

Balabanian, N., Fundamentals of Circuit Theory, Allyn and Bacon, Inc., Boston, Massachusetts, 1962

Brenner, E., and Javid, M., Analysis of Electric Circuits, McGraw-Hill Book Co., Inc., New York, N. Y., 1959

Carter, Robert C., Introduction to Electrical Circuit Analysis, Holt, Rinehart and Winston, New York, N. Y., 1966

Close, Charles M., The Analysis of Linear Circuits, Harcourt, Brace and World, Inc., New York, N. Y., 1966

Cutler, Phillip, and Hoover, Hardy, Electronic Circuit Analysis: Passive Networks, McGraw-Hill Book Co., Inc., New York, N. Y., 1960

Friedland, B., Wing, O., and Ash, R., Principles of Linear Networks, McGraw-Hill Book Co., New York, N. Y., 1961

Hammond, Seymour B., Electrical Engineering, McGraw-Hill Book Co., Inc., New York, N. Y., 1961

Jackson, H. W., Introduction to Electric Circuits, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1959

Mandl, Matthew, Fundamentals of Electric and Electronic Circuits, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1964

Nau, R. H., Alternating Currents and Network Analysis, The Ronald Press Company, New York, N. Y., 1962

Romanowitz, H. Alex., Electrical Fundamentals and Circuit Analysis, John Wiley and Sons, Inc., New York, N. Y., 1966

Siskind, Charles S., Direct and Alternating Current, McGraw-Hill Book Co., Inc., New York, N. Y., 1965, 2nd Edition

Skilling, H. H., Electrical Engineering Circuits, John Wiley & Sons, Inc., New York, N. Y., 1957

Skroder, C. E., and Helm, M. S., Circuit Analysis by Laboratory Methods, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1955

Van Valkenburg, M. E., Network Analysis, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1965, 2nd Edition

Walsh, J. B., and Miller, K. S., Introductory Electric Circuits, McGraw-Hill Book Co., New York, N. Y., 1960

CIRCUITS IV

(System Analysis)

HOURS REQUIRED

Class - 1; Laboratory - 4; Credit - 3.

DESCRIPTION

Circuits IV (System Analysis) is a project type course devoted to the study of complete electronic systems that are actually used in industry applications. The course will cover practical areas such as: Numerical control, telemetering, scientific data processing, coding and decoding techniques, control of manufacturing processes, and applications as they apply to specific industries.

INSTRUCTION PROCEDURE

Specific systems are studied from any published material that describes the operation and circuitry in reasonable detail. Textbooks, as such, are not used. Technical periodicals and instruction manuals, which are obtained directly from industry, are the two good sources of information. Although the course specifies four hours of laboratory time per week, no appreciable amount of experimental work is done for this course. The laboratory time is used for a study of the system, with the instructor's guidance, for the preparation of simplified circuit diagrams, and for the preparation of data and information pertaining to the system. Each student is expected to give a seminar-type report on one or more applications.

MAJOR DIVISIONS

	Class Hours	Laboratory Hours
I. How to Study and Understand Electronic Control Systems	2	8
II. Study of Specific Systems	3	12
III. Preparation and Organization of Reports on Systems	3	12
IV. Presentation of Oral Reports on Systems	3	12
	11	44

The above four major divisions represent the principal steps to be followed in order to satisfy the objectives of this course. The burden of responsibility of achieving these objectives is placed on the student. The class hours allotted for the course provide an opportunity for the instructor to give guidance and suggestions to the students as a group. The laboratory hours allotted for the course are to be used for independent student work with special assistance from the instructor.

Initially, the students are acquainted with techniques on how to study and understand published reports on electronic control systems. This means familiarity with the circuit diagrams of basic circuits to the point that he can identify these circuits by their identifying name, or by their function. It also means an understanding of a block diagram representation of systems.

When the student is assigned to study a specific system, he should first identify the practical purpose of the system and then examine the system until he understands the details of operation in every respect.

Three sets of instructions should be submitted to the student for his guidance in the study of control systems. These instructions are outlined under A, B, and C.

A. Suggestions on How to Study a Control System from Published Reports
   1. Know and Understand the general and specific problems that must be solved with the system. Do this on your own, as best you can, before you get into the details of the system.
   2. Identify the input and output circuits for the system. What are the signals and where are they in the system? What is the nature of the outputs? What is being done?
   3. Make a general inspection of the block diagram and/or the circuit diagram of the system. What types of circuits are used? Which ones are familiar to you?

4. The circuits, with which you are familiar, are good places from which to continue a study of the system. Work away from these known circuits. Knowing a particular circuit will help you to identify the circuits that precede and follow.
5. Keep asking yourself as you identify each circuit or group of circuits: Why is this circuit, or group of circuits, being used? Which of the specific problems of the system are being solved with these identified circuits? If you do not know the reason for the identified circuits, then you will have trouble in continuing your studies.
6. If you find yourself getting nowhere, then quit looking at the circuit--quit looking at the block diagram--quit reading the material that you have until a later time; but, do not quit or get hysterical.
7. What do you do, then? Put the material aside and review the specific problems that must be solved with the system. Are there any control problems which you might not have identified or do not fully understand? Know the control problems and you will know what the circuits must do. Know the purpose of the various circuits and you are prepared to continue a study of the system.
8. There are usually some circuits that you cannot identify because of the way the circuit is drawn. In such cases, redraw the circuit and see if you can make it take on a configuration that is familiar or that will permit you to interpret its function.

B. Presentation of Report

1. Give title, authors, source, and dates.
2. Describe briefly the main purpose of the system.
3. Identify and explain the specific problems (usually non-electrical) that must be considered for your particular system. This is an extremely important part of your report. It is not time consuming, but what you do here will influence how well you hold your audience through the remainder of the report.
4. Explain how the system operates. This is usually done with the aid of block diagrams, although other techniques of presentation are sometimes necessary. Use your own judgment and ingenuity, but try to avoid referring to actual circuit diagrams at this stage of your presentation.
5. Show and explain that circuitry which is most interesting, new, or unique.
6. Show the material that you had to work from.

C. Specific Techniques to Follow in the Presentation

1. Use transparencies with overhead projector as much as possible.
2. All material should be prepared in advance. Should not write on chalkboard during presentation.
3. Presentation must be extemporaneous. An outline or notes to guide you are not permissible. The reason: you will do a better job this way.
4. Assume you are presenting the report at a technical paper session of a professional society.

PHYSICS I

HOURS REQUIRED

Class - 3; Laboratory - 2; Credit - 4.

DESCRIPTION

Physics I serves as a foundational course in the sciences as support knowledge for electronic technology. It is of college level and is purposely of a comprehensive and general nature. Major concepts in scientific thought, interpretation of physical measurement and the basic models of modern atomic and molecular structure are examined.

INSTRUCTION PROCEDURE

Emphasis in both laboratory and lecture-demonstration should be on interpretive human factors in dealing with a disciplinary science. Subject matter is to be presented as being characteristically dynamic in nature, rather than consisting of facts and laws to be learned. Laboratory work should stress the proper use of equipment when using scientific methods, rather than "proving" laws which could be lobically developed and shown to be valid in the classroom. Although the instructor should be degreed in the subject area of physics, he should familiarize himself with the content and goals of the electronic technology program.

Supplementary notes may be required to support selected texts.

MAJOR DIVISIONS

	Class Hours	Laboratory Hours
I. The Nature of Physical Science	5	4
II. Physical Measurement and Data	13	8
III. The Structure and Behavior of Matter	15	10
	33	22

I. The Nature of Physical Science
  A. Class: 5 hours
    1. Historical and philosophical foundations
      a. The evolution of science
      b. The need for changes in conceptual thinking
    2. The branches of science, diagrammatic representation
    3. Scientific method
      a. Analytic approach
      b. Empirical attitude
    4. A definition of physics: a logical system of thought in a state of evolution
  B. Laboratory: 4 hours
    1. Laboratory orientation - 1 hour
    2. Observational exercises in approach, logic and deduction when dealing with experimental phenomena - 3 hours

II. Physical Measurement and Data
  A. Class: 13 hours
    1. The metric system
    2. Dimensional units of equations
    3. Scientific notation
      a. Powers of ten
      b. Exponents
    4. Important constants and conversion factors
    5. The role of the frame of reference in time and space and relativistic implications
    6. Measuring devices and applications
    7. Units and measurements in space
      a. Length
      b. Area
      c. Volume
      d. Density
      e. Mass
      f. Inertia
    8. Units and measurements in time
      a. Table of geological time and life
      b. Interval and epoch
      c. Apparent and mean solar time
      d. Mean sidereal time
      e. Atomic time
      f. Frequency standards
    9. Analysis and interpretation of data

a. Random error
b. Systematic error
c. Probability
d. Variation
e. Combination
f. Permutation
g. Distribution
h. Deviation

B. Laboratory: 8 hours

1. Analysis and measurement of length, area, volume, density, mass and time, stressing the mathematical validity of results and the magnitude of experimental error. Also to be explored are the nature of random and systematic errors, frequency distributions and the accuracy of the measuring instruments.

III. The Structure and Behavior of Matter

A. Class: 15 hours

1. The dual nature of matter
a. As a wave
b. As a particle
2. Antiparticles
3. Basic quantum concepts
a. Granularity
b. Probability
c. Annihilation and creation
d. Waves and particles
e. The uncertainty principle
4. Wave mechanics and atomic structure
5. Radioactivity and radioactive dating
6. Molecules and chemical bonding
a. Covalence
b. Ionic bonding
c. Metallic bonding
d. Van Der Waal's bonding
7. The electromotive series
8. Atomic and molecular resonance

B. Laboratory: 10 hours

1. Study of the probabilistic and random nature of quantum action by means of radioactive source and stop watch. Individual counts are recorded by a Geiger counter and are then collectively grouped to study the time and frequency distribution patterns.
2. The decay rates of unstable particles, their half-lives and simple cloud chamber experiments are to be studied.
3. The electromotive series is to be studied by assembling simple cells using a weak electrolyte and various combinations of metals as electordes.
4. The charge on an electron and Planck's constant are to be determined.
5. Ripple tanks are to be used in the study of wave mechanics.

SOME SUGGESTED TEXTS AND REFERENCES

Beiser, Arthur, Concepts of Modern Physics, McGraw-Hill Book Co., New York, N. Y.

Benumof, Reuben, Concepts in Physics, Prentice-Hall, Inc., Englewood Cliffs, N. J.

Carnap, Rudolph, Philosophical Foundations of Physics, Basic Books, New York, N. Y.

Companion, Audrey L., Chemical Bonding McGraw-Hill Book Co., New York, N. Y.

Division of Technical and Vocational Education, Instrumentation Technology, (OE-80033), U.S.O.E., Washington, D. C.

Duquesne, Maurice, Matter and Antimatter, Harper and Bros., New York, N. Y.

Feynmann, Leighton and Sands, Fehnmann Lectures on Physics, Addison-Wesley, Reading, Mass.

Ford, Kenneth W., The World of Elementary Particles, Ch. 3, Blaisdell Publishing Company, Waltham, Mass.

Gottlieb, Barbuny and Emmerich, Seven States of Matter, Walker Publishing Company, New York, N. Y.

Gray and Coutts, Man and His Physical World, 4th Ed., D. VanNostrand Co., Inc., Princeton, N. Y.

Halliday and Resnick, Physics, Part I, Part II, 2nd Ed., John Wiley and Sons, Inc., New York, N. Y.

Harnwell and Legge, Physics: Matter, Energy and the Universe, Reinhold Publishing Company, New York, N. Y.

Holton, Gerald, Physics and Culture, Bulletin, Inst. Phys. and Phys. Soc., Number 321-329.

Holton and Roller, Foundations of Modern Physical Science, Addison-Wesley, Reading, Mass.

Hooke, Robert, Introduction to Scientific Inference, Holden-Day, Inc., San Francisco, Calif.

Joseph, Pomeranz, Prince and Sacher, Physics for Engineering Technology, John Wiley and Sons, Inc., New York, N. Y., 1966

Kaempffer, The Elements of Physics, Blaisdell Publishing Company, Waltham, Mass.

Melissinos, Adrian C., Experiments in Modern Physics, Academic Press, Inc., New York, N. Y.

Milne, E. A., Vectorial Mechanics, Methuen & Co., Ltd., London

Pearson, J. M., A Theory of Waves, Allyn and Bacon, Inc., Boston, Mass.

Pierce, John R., Quantum Electronics, Doubleday and Co., Garden City, N. Y.

Rense, William A., Physical Science, Blaisdell Publishing Company, Waltham, Mass.

Rosen, Siegfried and Dennison, Concepts in Physical Science, Harper and Row, New York, N. Y.

Sears and Zemansky, University Physics, Addison-Wesley Publishing Company, Reading, Mass.

Smith and Cooper, Elements of Physics, McGraw-Hill Book Co., New York, N. Y.

Stevenson and Moore, Theory of Physics, W. B. Saunders Co., Philadelphia, Pa.

Towne, Dudley H., Wave Phenomena, Addison-Wesley Publishing Company, Reading, Mass.

Young, Hugh D., Statistical Treatment of Experimental Data, McGraw-Hill Book Co., New York, N. Y.

PHYSICS II

HOURS REQUIRED

Class - 3; Laboratory - 2; Credit - 4.

DESCRIPTION

Physics II is a continuation of Physics I, stressing the structural development of matter in its various forms and a study of the interactions of matter as they are interpreted through the concepts of force, motion and energy.

INSTRUCTION PROCEDURE

The sequencing of topics is designed to develop relational concepts in physics. Stress should be placed on vector interpretations and solutions wherever possible. The vibrational and harmonic aspects of matter in motion must be closely correlated with concepts of resonance, interference and energy transfer as observed by physical measurement. It may be desirable to expand the sections on two-body problems and orbital mechanics to include current topics in satellite and space applications. Supplementary notes may be required to support selected texts.

MAJOR DIVISIONS

	Class Hours	Laboratory Hours
I. Gases, Liquids, Solids, Plasmas	15	10
II. Laws of Force, Motion and Energy	18	12
	33	22

- I. Gases, Liquids, Solids, Plasmas
  - A. Class: 15 hours
    - 1. Gases
      - a. Pressure and temperature effects
        - (1) Thermodynamics
        - (2) Entropy
        - (3) Heat engines and cycles
        - (4) Change of state
      - b. Active and inert gases
      - c. Dense gases and plasmas, the sun
      - d. Composition of the atmosphere
      - e. Transmission of gaseous vibration
        - (1) Velocity of sound in gases
        - (2) The audible spectrum
        - (3) Sound pressure, loudness, the decibel
        - (4) The Doppler effect
        - (5) Interference
        - (6) Standing waves and resonance
        - (7) The natural harmonic series
        - (8) Transducers
    - 2. Liquids
      - a. Pressure and temperature effects
        - (1) Freezing
        - (2) Heat of fusion and regelation
        - (3) Heat of vaporization
        - (4) Evaporation
      - b. Density of liquids
      - c. The nature of fluidity
        - (1) Viscosity and flow
        - (2) Cohesion
        - (3) Adhesion
    - 3. Solids
      - a. Pressure and temperature effects
        - (1) Elasticity, rigidity, tensile strength
        - (2) Coefficient of expansion
        - (3) Change of state, oxidation, sublimation
      - b. Density and mass
      - c. Transmission of vibration
      - d. Friction
  - B. Laboratory: 10 hours
    - 1. The gas laws are to be examined under variations of temperature and pressure
    - 2. Standing waves and air column resonance are to be studied with both single and mixed frequencies
    - 3. The relationship between loudness and frequency should be de-

termined aurally and related to the Fletcher-Munson curves
4. The heats of fusion and vaporization are to be examined
5. The coefficient of expansion for various materials should be determined
6. The natural resonant frequency of vibrating solids should be investigated

II. Laws of Force, Motion and Energy
 A. Class: 18 hours
  1. Sine and cosine laws
  2. Vector representation
   a. Resolution of forces
   b. Graphical solution
  3. Equilibrium
  4. Inertia and mass
   a. Gravitational mass
   b. Inertial mass
  5. Dynamics of translatory and rotational motion
   a. Centripetal acceleration
   b. Centripetal force
   c. Centrifugal force
  6. Periodic motion
   a. The pendulum
   b. Two-body problems
   c. Tides and the moon
   d. General structure of the solar system
   e. Elementary celestial and orbital mechanics
  7. Oscillations and oscillatory damping
  8. Work and energy
   a. The conservation of energy
   b. Potential energy, energy at rest
   c. Kinetic energy, energy in motion
   d. Work energy
    (1) Mechanical work
    (2) Heat and work
   e. Heat energy
    (1) The mechanical equivalent of heat
    (2) Thermodynamics
    (3) Isothermal and adiabatic changes
    (4) The Carnot cycle
   f. Exchange of heat
    (1) Convection
    (2) Conduction
    (3) Radiation
 B. Laboratory: 12 hours
  1. Vector analysis should be studied with the aid of force tables and measuring devices. Vector forces should be examined as both mass and velocity are varied.
  2. The value of the earth's gravitational constant should be deternined with the aid of pendulum techniques.
  3. Rotational and harmonic motions are to be explored experimentally.
  4. The mechanical equivalent of heat is to be determined.
  5. The efficiency of various radiators and/or heat sink construction is to be evaluated.

SOME SUGGESTED TEXTS AND REFERENCES

(See listing with Physics I)

PHYSICS III

HOURS REQUIRED

Class - 3; Laboratory - 2; Credit - 3.

DESCRIPTION

This course is a continuation of Physics I and II and is designed to develop an understanding of the visible and invisible electromagnetic spectrum, the nature of electric fields and forces, and the relationship of high energy physics to atomic conversion processes.

INSTRUCTION PROCEDURE

The topics in Physics III should be correlated with the foundational concepts established during the previous two quarters. The notions of quants, vector representation, energy in motion and dependence on operational models should be applied directly to the study of the nature and conversion of light and radiated energy, electric vector fields and the principles of energy transformation.

MAJOR DIVISIONS

	Class Hours	Laboratory Hours
I. Light Energy and Optics	12	8
II. Magnetism and Electricity	12	8
III. High Energy Physics	9	6
	33	22

I. Light Energy and Optics
A. Class: 12 hours
1. The propagation and velocity of light
2. The dual nature of light
a. As a wave
b. As a particle
c. The quantum and statistical aspects of emission
d. Definition of the photon
3. The special theory of relativity
4. The complete electromagnetic spectrum
a. The visible spectrum
(1) Spectra and color
(2) Helmholtz and Land Theories of color vision
(3) Illumination and lighting
(a) Luminescense
(b) Phosphorescense
b. The near-visible spectrum
(1) Infra-red radiation
(2) Ultra-violet radiation
5. Characteristics of optical devices
a. Mirrors
b. Lenses
c. Prisms
(1) Reflection
(2) Refraction
(3) Abberation
d. Real and virtual images
e. Image resolution
(1) The microscope
(2) The telescope
6. Absorption bands
7. Polarization of electromagnetic waves
8. Optical interference patterns
9. Optical resonance and optical pumping
10. Coherent radiation
a. Lasers
b. Masers
11. Holography
12. Conversion of radiated energy
a. Heat from energy absorption
b. Electricity from energy absorption
B. Laboratory: 8 hours
1. The inverse-square law should be verified for both visible and non-visible radiation
2. The combination of various wave lengths of both visible and non-visible radiation are to be investigated
3. The polarization of light and absorption spectra in gases is to be examined
4. The wave length of radiated energy is to be determined by use of a laser beam
5. Holographic plates are to be prepared and investigated

II. Magnetism and Electricity
  A. Class: 12 hours
    1. Magnetic attraction and repulsion
      a. Terrestial magnetism
      b. Magnetic materials
      c. Hysteresis
      d. B and H curves
    2. Electrostatic charge
    3. Potential and its measurement
      a. Standard cells
    4. Electromagnetism
      a. Electromagnetic induction
    5. Capacitance
      a. Dielectric materials
    6. Resistance
      a. Insulators
      b. Semi-conducting materials
      c. Conductors
      d. Superconductivity
    7. Electron flow and emission
      a. Dependence on temperature
      b. Electron flow in solids
      c. Electron flow in liquids (electrolytes)
      d. Electron flow in gases
      e. Electron flow in a partial vacuum
        (1) The thermionic diode
        (2) Multi-element vacuum tubes
    8. Semi-conductor electronics
      a. P-type and N-type materials
      b. Doped junctions
      c. Junction devices, diodes, Zener diodes
      d. Free electrons and holes
      e. The simple transistor
      f. Monolithic devices and integrated circuitry
  B. Laboratory: 8 hours
    1. Electric fields are to be investigated by means of a current carrying wire and simple compass
    2. Determination of magnetic field strength by direct measurement and by means of oxide powder distribution on non-conductive surface held above magnetic devices
    3. Plot of B and H curves for different iron samples
    4. Calibration of instruments using a standard cell
    5. The deflection of an electron beam by electrostatic and electromagnetic means is to be investigated

III. High Energy Physics
  A. Class: 9 hours
    1. High energy sources, terrestial and extra-terrestial
    2. Methods of recording high energy activity
      a. Photographic plate
      b. Cloud chamber
      c. The Geiger counter and scintillation counter
    3. Nuclear Fiesion
    4. Nuclear Fusion
    5. Isotopes
    6. Particle accelerators
      a. The Van de Graff generator
      b. The cyclotron
      c. The betatron
      d. The betatron-cynchrotron
      e. The proton synchrotron
      f. Lonear accelerators
    7. Practical conversion of atomic energy
  B. Laboratory: 6 hours
    1. Detection of particle emission of radioactive sources in the laboratory
    2. Detection and measurement of cosmic particles
    3. Recording of particle tracks on photographic film and by means of simple cloud chamber

SOME SUGGESTED TEXTS AND REFERENCES

(See listing with Physics I)

MECHANICAL DRAFTING

HOURS REQUIRED

Class - 1; Laboratory - 6; Credit - 3.

DESCRIPTION

The course is designed to introduce the student to drafting fundamentals involving principles of orthographic projection, theory of pictorial drawing, freehand sketching, basic dimensioning, fasteners, and working drawings.

INSTRUCTION PROCEDURES

The course should be presented as a fundamental course in mechanical drafting, involving the various techniques of drafting as found in industry. The course objective is to introduce the student to a variety of jobs and provide him with greater flexibility in adapting the knowledge of drafting to the field of electronics.

Supplementary notes may be required to support selected texts.

MAJOR DIVISIONS

		Class Hours	Laboratory Hours
I.	Fundamentals of Mechanical Drafting	1	6
II.	Orthographic Projection and Technical Sketching	2	12
III.	Isometric and Oblique Drawings	1	6
IV.	Auxiliary Views (Engineering Geometry) and Sections	2	12
V.	Dimensioning	2	12
VI.	Fasteners	1	6
VII.	Working and Assembly Drawings	2	12
		11	66

I. Fundamentals of Mechanical Drafting
  A. Class: 1 hour
    1. Lettering
      a. Lettering styles
      b. Freehand techniques
      c. Mechanical lettering guides, pencils and pens
    2. Drawing instruments
      a. Use and care
      b. Drafting techniques
      c. Standards
  B. Laboratory: 6 hours
    1. Projects involving lettering styles stressing weight, shape, size, and spacing
    2. Lettering projects using lettering guides
    3. Projects involving elementary geometrical constructions and figures stressing the use of instruments
    4. Freehand sketching projects of elementary geometric figures, involving straight and curved lines

II. Orthographic Projection and Technical Sketching
  A. Class: 2 hours
    1. Fundamentals of Projection
      a. Theory of projection
      b. Techniques of projection
    2. Orthographic projection
      a. Planes of projection
      b. Position of objects in relation to planes
      c. Selection and layout of multiview drawings
      d. Relationship of lines and planes to principal coordinate planes
    3. Freehand sketching
      a. Techniques of sketching, shading, and proportioning
      b. Isometric sketching
      c. Oblique sketching
  B. Laboratory: 12 hours
    1. Projects covering freehand sketching of various figures involving isometric and oblique principles
    2. Projects involving relationships of lines and planes to principal coordinate planes
    3. Projects involving missing lines and views

- III. Isometric and Oblique Drawings
    - A. Class: 1 hour
        - 1. Isometric drawing
            - a. Theory of projection
            - b. Isometrics of planes, solids, and curved figures
            - c. Dimensioning isometric drawings
            - d. Sectional views
        - 2. Oblique drawing
            - a. Theory of projection
            - b. Methods of construction
            - c. Dimensioning oblique drawings
    - B. Laboratory: 6 hours
        - 1. Isometric drawing projects
        - 2. Oblique drawing projects

- IV. Auxiliary Views (Engineering Geometry) and Sections
    - A. Class: 2 hours
        - 1. Relation of auxiliary plane to principal planes and to the object
        - 2. Construction of principal views by auxiliary techniques
        - 3. Relationship of points, lines, planes, and warped surfaces
            - a. True length, size, and position
            - b. Geometry relationships
        - 4. Types of sections
        - 5. Techniques of sectioning
    - B. Laboratory: 12 hours
        - 1. Projects on the construction of auxiliary views to show true shapes
        - 2. Projects on the construction of principal views by using auxiliary views
        - 3. Projects involving practical problems stressing relationship between lines and planes
        - 4. Projects on the sectioning of various views from different positions
        - 5. Projects on sectioning hidden parts

- V. Dimensioning
    - A. Class: 2 hours
        - 1. General dimensioning
            - a. Dimensioning techniques
            - b. Size dimensioning
            - c. Notes and symbols
        - 2. Shop terms and processes
            - a. Castings
            - b. Forgings
            - c. Machine shop processes
        - 3. Material specifications
        - 4. Tolerances
    - B. Laboratory: 12 hours
        - 1. Dimensioning of simple machine parts
        - 2. Projects dimensioning more complex machine parts involving tolerances, finished surfaces, and material specifications

- VI. Fasteners
    - A. Class: 1 hour
        - 1. Screw threads
            - a. Nomenclature
            - b. Types
            - c. Thread series
            - d. Classes of fits
        - 2. Representation of threads
            - a. Conventional
            - b. Simplified conventional
        - 3. Representation of fasteners
            - a. Bolts and nuts
            - b. Screws
            - c. Keys and springs
        - 4. Specifications of threads and fasteners on drawings
    - B. Laboratory: 6 hours
        - 1. Projects covering conventional drawings of various threads and fasteners
        - 2. Projects involving conventional representation of fasteners applicable to machine design

- VII. Working and Assembly Drawings
    - A. Class: 2 hours
        - 1. Working drawings
            - a. Requirements for complete working drawings
            - b. Drawing revision
        - 2. Assembly drawings
            - a. Types
            - b. Dimensioning and sectioning practices
            - c. Listing of parts
    - B. Laboratory: 12 hours
        - 1. Projects covering complete working drawings of machines
        - 2. Projects on the complete assembly and drawings corresponding to working drawings

SOME SUGGESTED TEXTS AND REFERENCES

Arnold, J. N., Introductory Graphics, McGraw-Hill Book Co., New York, N. Y. 1958

Douglas, C. E. & Haag, A. L., Descriptive Geometry, Holt, Rinehart, & Winston, Inc., New York, N. Y., 1962

French, T. E. & Vierck, C. J., Graphic Science, 2nd Ed., McGraw-Hill Book Co., New York, N. Y., 1963

French, T. E. & Vierck, C. J., A Manual of Engineering Drawings for Students and Draftsmen, 9th Ed., McGraw-Hill Book Co., Inc., New York, N. Y., 1960

Giesecke, F. E., Mitchell, A., & Spencer, H. C., Technical Drawing, 4th Ed., The Macmillan Company, New York, N. Y. 1958

Hoelscher, R. P., Springer, C. H. & Dobrovolny, J. S., Engineering Drawing and Geometry, 3rd Ed., John Wiley & Sons, Inc., New York, N. Y., 1968

Hoelscher, R. P., Springer, C. H., & Dobrovolny, J. S., Basic Drawing for Engineering Technology, John Wiley & Sons, Inc., New York, N. Y., 1964

Luzadder, W. J., Basic Graphics, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1962

Pare, E. G., Engineering Drawing, Holt, Rinehart & Winston, Inc., New York, N. Y., 1959

Rising, J. S. & Almfeldt, M. W., Engineering Graphics, 2nd Ed., Wm. C. Brown Book Co., Dubuque, Ia., 1959

Springer, R. D., Bullen, P. W., Kleinhers, W. A., & Palmer, L. G., Basic Graphics: Drawing and Descriptive Geometry, Allyn & Bacon, Inc., College Division, Boston, Mass., 1963

Warner, F. M. & McNeary, M., Applied Descriptive Geometry, 5th Ed., McGraw-Hill Book Co., Inc., New York, N. Y., 1959

Zezzora, F., Engineering Drawing, 2nd Ed., McGraw-Hill Book Co., Inc., New York, N. Y., 1959

ELECTRONIC DRAFTING

HOURS REQUIRED

Class - 1; Laboratory - 6; Credit - 3.

DESCRIPTION

The course is designed to introduce students to electronic symbols, mathematical symbols, electronic devices, basic circuitry, basic electronic systems, and drafting techniques and fabrication processes as used by the electronics industry.

INSTRUCTION PROCEDURES

The purpose of the course in electronic drafting is to familiarize the student with electronic circuitry, symbols, and processes. The course objective is to develop recognition of electronic components and systems that allow the student to learn the language of electronics.

In addition to using a suitable textbook on electronic drafting, the course should be supplemented with electronic drafting problems related to current electrical systems and components that can be directly obtained from recent technical publications and library references. It is suggested that the drafting problems throughout the course be so designed as to emphasize the correlation of mathematical and electronic symbols to each schematic layout. On schematic diagrams, actual circuit response should be indicated. This may be done by identifying the waveforms at various points.

Supplementary notes may be required to support selected texts.

MAJOR DIVISIONS

		Class Hours	Laboratory Hours
I.	Standard Electronic Symbols	1	6
II.	Standard Mathematical Symbols for Electronics	1	6
III.	Graphing Techniques	2	12
IV.	Basic Circuits and Equivalent Models	2	12
V.	Wiring or Connecting Diagrams	1	6
VI.	Modular Circuits	2	12
VII.	Schematic Diagrams of Typical Electronic Systems	2	12
		11	66

I. Standard Electronic Symbols
- A. Class: 1 hour
  1. Dependent or passive elements (resistors, capacitors, switches, relays, and transistors)
  2. Independent or active elements (voltage and current sources, tubes, transistors, and generators)
  3. Symbols for electronic units and systems (logic units, modules, and packaged electronic circuits)
  4. Engineering standards and specifications (IEEE, ASA, and military)
  5. Electronic templates and stencils
  6. Connector and insulator symbols
  7. Sketching techniques (pictorial illustrations of electrical components)
- B. Laboratory: 6 hours
  1. Projects on basic electrical parameter symbols
  2. Projects on voltage and current sources and equivalent models
  3. Projects on electrical unit and system symbols
  4. Projects on different standards and specifications
  5. Projects on connectors and insulators
  6. Pictorial sketches of electronic components.

II. Standard Mathematical Symbols for Electronics
- A. Class: 1 hour
  1. Mathematical symbols and definitions
     - a. Lower case letters (instantaneous values)
     - b. Upper case letters (magnitudes and phasors)
     - c. Voltage and current source

symbols for tubes (E_{bb} and E_c) and transistors (V_{cc} and V_{BB})
d. Electrical units (μv, K, meg-Hz)
e. Color codes and charts for resisters and capacitors
2. Equivalent circuit parameters for transistors
3. Equivalent circuit parameters for tubes
4. Greek letter symbols and angle representation
5. Algebraic symbols for mathematical notation and operations
6. Mathematic representation of basic laws of electronics

B. Laboratory: 6 hours
1. Projects on mathematical symbols
2. Projects on equivalent circuit parameters
3. Projects on algebra-trigonometric symbols
4. Projects on basic formulas of electronics

III. Graphing Techniques
A. Class: 2 hours
1. Graphing circuit parameters (Ohm's Law, resistive charts, transfer curves, characteristic curves and frequency response)
2. Identifying and graphing trigonometric waveforms (sine, cosine, and tangent curves in both degrees and radians)
3. Identifying and graphing non-sinusoidal waveforms (ramps, steps, and spikes)
4. Identifying and graphing exponentials and logarithms (semi-log graphs and log-log graphs)
5. Techniques of phasor analysis
a. Addition and subtraction of phasors
b. Locus diagrams
c. Complex plane and S-plane
d. Polar co-ordinates
6. Graphical solutions of waveforms (point-by-point analysis)

B. Laboratory: 12 hours
1. Projects on graphing circuit parameters
2. Projects on graphing sinusoidals
3. Projects on graphing exponentials and logarithmic curves
4. Projects on vector analysis
5. Projects on graphical solutions of waveforms

IV. Basic Circuits and Equivalent Models
A. Class: 2 hours
1. Techniques of modular layout (grids)
2. Techniques of schematic layout of basic circuits
3. Familiarization of basic circuits using layout techniques

B. Laboratory: 12 hours
1. Projects on basic circuits
a. Amplifiers
b. Bridge circuits
c. Filter circuits
d. R-L-C circuits
e. Oscillators
f. Power supplies
g. Multivibrators
h. Switching circuits
2. Projects on equivalent models of basic circuits
3. Projects on modular layout
4. Projects on schematic layout

V. Wiring or Connecting Diagrams (Flow Diagrams)
A. Class: 1 hour
1. Power systems (wiring and cable diagrams)
a. Distribution center and transformers
b. Power-factor correction units
c. Distribution busses
d. Lighting
e. Components and insulators
2. Electronic systems (wiring and cable diagrams)
a. Automatic control systems
b. Automatic measuring systems
c. Logic diagrams

B. Laboratory: 6 hours
1. Projects developing flow diagrams
2. Projects on commercial and industrial power systems
3. Projects on electronic control and measuring systems
4. Projects on wiring-assembly drawings

- VI. Modular Circuits
  - A. Class: 2 hours
    - 1. Printed circuitry
      - a. Techniques of masking
      - b. Photographic process
      - c. Etching process
    - 2. Integrated circuits (micro-circuits)
      - a. Thin-film
        - (1) Hybrid circuits
        - (2) Packaging
      - b. Semiconductors
        - (1) Silicon wafers
        - (2) Thermionic integrated micro-module approach (TIMM)
        - (3) Microelectronics (solid-block circuits and systems)
        - (4) Packaging
        - (5) Hybrid circuits
  - B. Laboratory: 12 hours
    - 1. Projects on printed circuitry
    - 2. Projects on thin-film circuits
    - 3. Projects on semiconductors
- VII. Schematic Diagrams of Typical Electronic Systems
  - A. Class: 2 hours
    - 1. Preparation of block diagrams of various electron systems
      - a. Signal flow diagrams
      - b. Block diagrams of systems
    - 2. Preparation of schematic diagrams of various systems (follow-through on block diagrams)
    - 3. Specification techniques and parts lists
    - 4. Chasis layout (mechanical and pictorial layouts)
  - B. Laboratory: 12 hours
    - 1. Projects developing block diagrams of electronic systems
    - 2. Projects developing schematics of block diagrams
    - 3. Preparation of electronic schematics including specifications and parts list as a problem solving project
    - 4. Projects on chasis layout

SOME SUGGESTED TEXTS AND REFERENCES

Baer, Charles J., Electrical and Electronic Drafting, McGraw-Hill Book Co., New York, N. Y., 1966

Carini, L. F. B., Drafting for Electronics, McGraw-Hill Book Co., New York, N. Y. 1946

Doyle, J. M., Thin-Film and Semiconductor Integrated Circuitry, McGraw-Hill Book Co., New York, N. Y., 1966

Kirshner and Stone, Exercises in Electronic Drafting, McGraw-Hill Book Co., New York, N. Y., 1966

Kirshner and Stone, Electronic Drafting Workbook, McGraw-Hill Book Co., New York, N. Y., 1966

Kuller, Karl K., Electronic Drafting, McGraw-Hill Book Co., New York, N. Y., 1962

Kvamme, E. Floyd and Bieler, L. H., Fairchild Semiconductor Integrated Circuits, Fairchild, Mountain View, California, 1966

Novak, W. J. and McPartland, J. P., Electrical Design Details, McGraw-Hill Book Co., New York, N. Y., 1962

Raskhodoff, Nicholas M., Electronic Drafting and Design, Prentice-Hall, Inc., Englewood Cliffs, N. J., 1966

Romanowitz, H. Alex, Fundamentals of Semiconductors and Tube Electronics, John Wiley and Sons, Inc., New York, N. Y., 1962

Shiers, George, Electronic Drafting, Prentice-Hall, Inc., Englewood Cliffs, N. J., 1962

COMMUNICATION SKILLS I

HOURS REQUIRED

Class - 3; Credit - 3.

DESCRIPTION

First of two courses in communication skills. A course in the mechanics of writing and speaking through study, analysis, and practice. Stress is on elimination of mechanical errors and possible sources of misinterpretation.

INSTRUCTION PROCEDURE

Because of the nature of these courses it is essential that they be taught in an atmosphere of free thinking, exchange of ideas, and spontaneity. This is most easily attained when the class is taught as a seminar.

The courses were formulated on the idea that technical students have communication needs considerably different from those of liberal arts students. Technical students are rarely interested in studying writing and literature for the sake of study alone; they need to apply the communication skills to their technical studies.

These courses were designed to take advantage of the technical student's analytical mind. They are presented with an emphasis on logic and scientific organization to provide a tie-in with the technical subjects.

MAJOR DIVISIONS

		Class Hours
I.	Mechanics of Writing	12
II.	Mechanics of Speech	12
III.	Logic and Introduction to Clarity Analysis	9
		33

I. Mechanics of Writing
Class: 12 hours

1. Grammar
2. Sentence structure
3. Paragraph structure
4. Punctuation
5. Word usage
6. Organization and structure of the paper as a whole

II. Mechanics of Speech
Class: 12 hours

1. Preparation
   a. Content
      (1) Accumulation of material
      (2) Reduction and elimination of material
      (3) Level
   b. Organization
   c. Visual aids
2. Presentation
   a. Voice and projection
   b. Use of gestures
   c. Visual aids
   d. Methods of emphasis
3. Types of speeches
   a. Informative
   b. Entertainment
   c. Argumentative
   d. Persuasive
      (1) Intellectual
      (2) Emotional

III. Logic and Introduction to Clarity Analysis
Class: 9 hours

1. Introduction
   a. Need for common logic
   b. Relation of logic to language
   c. Clarity analysis: the isolation of logic
2. Reasoning
   a. Deductive reasoning
      (1) Methods
      (2) Common areas of use
   b. Inductive reasoning
      (1) Methods
      (2) Uses
3. Application to communication
   a. Logic differences between groups
      (1) Groups separated by language
      (2) Groups separated by economic class
      (3) Groups separated by education
   b. Logic similarities between groups
   c. Maximizing communication through stress of logic similarities
   d. Speed reading through the logic of organization

For list of texts and references, see Communication Skills II

COMMUNICATION SKILLS II

HOURS REQUIRED

Class - 3; Credit - 3.

DESCRIPTION

Second of two courses in communication skills. A study of the problems involved in communication and the elimination of them through analysis and practice. Stress is on minimizing misinterpretation through development of logical presentation techniques.

INSTRUCTION PROCEDURE

Because of the nature of these courses it is essential that they be taught in an atmosphere of free thinking, exchange of ideas, and spontaneity. This is most easily attained when the class is taught as a seminar.

The courses were formulated on the idea that technical students have communication needs considerably different from those of liberal arts students. Technical students are rarely interested in studying writing and literature for the sake of study alone; they need to apply the communication skills to their technical studies.

These courses were designed to take advantage of the technical student's analytical mind. They are presented with an emphasis on logic and scientific organization to provide a tie-in with the technical subjects.

MAJOR DIVISIONS

		Class Hours
I.	Development of Communication	3
II.	The Language	4
III.	Effective Listening and Watching	4
IV.	Effective Speaking	8
V.	Efficient Reading	5
VI.	Effective Writing	9
		33

I. Development of Communication
   Class: 3 hours
   1. Development of thought processes and logic
      a. Inception of an idea
      b. Need to transfer the idea
   2. The spoken work - the critical point
      a. Arbitrary choice of a word to present a thought
      b. Difference in meaning between speaker and listener
         (1) Conotation
         (2) Denotation
      c. Presentation of alternate words for more precise transfer
   3. The written work
      a. Formalization of speech
      b. The need for rules of form
      c. Lack of repetition

II. The Language
   Class: 4 hours
   1. Nature of the language
      a. Growth
      b. Changes
   2. Elements of the language
      a. Words
      b. Groups of words
   3. Different uses and methods
      a. Persuasive
      b. Explanatory

III. Effective Listening and Watching
   Class: 4 hours
   1. Analysis of motive
      a. Speaker
      b. Listener
   2. Differences of media
      a. Radio
      b. Television
      c. Motion pictures
      d. Theater

IV. Effective Speaking
   Class: 8 hours
   1. The speaker as a listener
   2. Formal speech
   3. Informal speech
   4. Discussion

V. Efficient Reading
   Class: 5 hours
   1. Differences in motivation
      a. Reading for ideas
      b. Reading for understanding
      c. Reading for relaxation
   2. Forms of printed media

VI. Effective Writing

Class: 9 hours

1. Objective forms
   - a. Process exposition
   - b. Definition
   - c. The report
   - d. The documentary
2. Subjective forms
   - a. Autobiography
   - b. Letters
   - c. The essay
   - d. The portrait
   - e. The satire
3. The beautification process
   - a. Use of illustrations, diagrams, etc.
   - b. The physical appearance of the writing

SOME SUGGESTED TEXTS AND REFERENCES

Greever, G., and Jones, E. S., The Century Handbook of Writing, Appleton-Century-Crofts, Inc., New York, N. Y.

Salisbury, R., Better Language and Thinking, Appleton-Century-Crofts, Inc., New York, N. Y.

Strunk, W., and White, E. B., Style in Writing, The Macmillan Company, New York, N. Y.

Hayakawa, S. I., Language in Action, Harcourt, Brace & Co., New York, N. Y.

Wilson, H. W., and Locke, L. G., The University Handbook, Holt, Rinehart and Winston, New York, N. Y.

Collegiate Dictionary (preferably Merriam-Webster, World Publishing Co., or equivalent)

TECHNICAL REPORT WRITING

HOURS REQUIRED

Class - 3; Credit - 3.

DESCRIPTION

This is the last course in technical communications. It is primarily a course in the mechanics of writing and speech as specifically applied to technical presentation. Stress is on the development of finesse in technical reporting through analysis and practice.

The final section of the course is the formal presentation of a technical report, both in written and oral form, by each student.

Prerequisite: Communication Skills I and II.

INSTRUCTION PROCEDURE

It would be desirable, in the section on printing processes, for students to familiarize themselves with problems of a printer. This is perhaps most easily accomplished by taking field trips to several local commercial printing establishments.

If practicable, in the section on the term project, it would be of value to have all formal reports of the class printed in booklet form and distributed among students. Also, where funds and equipment are available, it would benefit each student to have his oral presentation taped, or, better yet, videotaped, so that he may evaluate his own performance in addition to those of his classmates.

MAJOR DIVISIONS

		Class Hours
I.	Technical Writing	8
II.	Printing Processes	3
III.	Design Techniques	8
IV.	Technical Presentation	4
V.	Term Project	10
		33

I. Technical Writing
  Class: 8 hours
  1. Forms
    a. Engineering reports
    b. Specifications
    c. Proposals
    d. Operation and instruction manuals
    e. Technical papers
    f. Magazine articles
    g. Abstracts
    h. Advertisements
    i. Catalogs
  2. Common objectives of technical writing
    a. Precision, accuracy
    b. Brevity
  3. Techniques of technical writing
    a. Paragraphing
    b. Simple wording
    c. Sentence length
    d. Cliches and jargon
    e. Salesmanship
    f. Avoiding the "negative" approach

II. Printing Processes
  Class: 3 hours
  1. Relief: letterpress, multigraph, rubber stamp
  2. Planographic: offset, multilith, photogelatin, hectograph, spirit duplicator
  3. Intaglio: gravure, rotogravure, engraving
  4. Stencil: mimeograph, silk screen
  5. Photographic: photography, photostat, blueprint, whiteprint
  6. Miscellaneous: xerography, thermofax

III. Design Techniques - Maintenance Manual
  Class: 8 hours
  1. Organization - reader function and level
    a. Front matter as used by management, buyer, etc.; non-technical
    b. Simplified instructions as used by operator; low technology
    c. Detailed instructions, as used by servicemen, installers; high technology
    d. Support matter, as used to supplement detailed instructions

2. Layout and design
    a. Illustrations and artwork
        (1) Functions
        (2) Uses
        (3) Types
            (a) Drawings
            (b) Photographs
            (c) Graphs and charts
    b. Significance of appearance
        (1) Effect on reading case
        (2) Effect on attention
            (a) Initial
            (b) Lasting

IV. Technical Presentation
Class: 4 hours
1. Considerations
    a. Motivation
        (1) Speaker
        (2) Audience
    b. Background of audience
    c. Location, room size, and related items
2. Organization
3. Techniques
    a. Illustrations
    b. Handouts
    c. Demonstrations

V. Term Project
Class: 10 hours
1. Written report, as if published in a professional journal, to be mimeographed and handed out to class
2. Oral report, as presented to a meeting of a professional society

SOME SUGGESTED TEXTS AND REFERENCES

Bryant, D. C., and Wallace, K. R., Oral Communication, Appleton-Century-Crofts, New York, N. Y.

Crouch, W. G., and Zetler, R. L., A Guide to Technical Writing, Ronald Press Co., New York, N. Y.

Gaum, C. G., Graves and Hoffman, Engineering Reports, Prentice-Hall, Inc., Englewood Cliffs, N. J.

Harwell, G. C., Technical Communications, Macmillan Co., New York, N. Y.

Marder, D., The Craft of Technical Writing, Macmillan Co., New York, N. Y.

Melcher, D., and Larrick, N., Printing and Promotion Handbook, McGraw-Hill Book Co., Inc., New York, N. Y.

Menzel, D. H., Jones, H. M., and Boyd, L. G., Writing a Technical Paper, McGraw-Hill Book Co., Inc., New York, N. Y.

Reisman, S. J., A Style Manual for Technical Writers and Editors, Macmillan Co., New York, N. Y.

Turner, R. P., Technical Writer's and Editor's Stylebook, Howard W. Sams & Co., Inc., Indianapolis, Ind.

Tweney, C. F., and Hughes, L. E. C., Chamber's Technical Dictionary, 3rd Ed., Macmillan Co., New York, N. Y.

Van Hagan, C. E., Report Writer's Handbook, Prentice-Hall, Inc., Englewood Cliffs, N. J.

Weil, B. H., The Technical Report, Reinhold Publishing Corp., New York, N. Y.

Wilcox, S. W., Technical Communication, International Textbook Co., Scranton, Pa.

PSYCHOLOGY AND HUMAN RELATIONS

HOURS REQUIRED

Class - 4; Credit - 4.

DESCRIPTION

Planned for the development of a better understanding of the human mechanism; its motivation and learning ability as related to interpersonal relations on the job. Employee selection, intelligence and aptitude tests, and introduction to supervision.

MAJOR DIVISIONS

		Class Hours
I.	A Practical Science	3
II.	Basic Psychological Principles	14
III.	Problems of Adjustment	9
IV.	Vocational Industrial Problems	12
V.	Factors of Supervision	6
		44

I. A Practical Science
Class: 3 hours
1. Orientation to subject: posing and solving problems from life situations
2. The scientific method:
   a. Awareness of problems
   b. Collection of data
   c. Hypothesis
   d. Testing hypothesis
   e. Confirmation of refutation

II. Basic Psychological Principles
Class: 14 hours
1. Motivation
   a. Nature and classification of motives
   b. Importance in understanding, predicting and controlling human behavior
   c. Application to advertising, business and industry
2. Emotions and Feelings
   a. Origin, function and physical aspects
   b. Understanding and controlling
3. Frustration
   a. Causes
   b. Various reactions to frustration
   c. Application to industrial problems

III. Problems of Adjustment
Class: 9 hours
1. Abnormal reaction patterns
   a. Dynamics of mental and emotional disorders
   b. Chief classifications of disorders
   c. Principles of general semantics and relevance to understanding of abnormal reactions
2. Mental hygiene
   a. Kinds of therapy and their rationals
   b. Exploration of the concept of mental health
   c. Achieving and maintaining mental health

IV. Vocational Industrial Problems
Class: 12 hours
1. Vocational problems: vocational choice
   a. Factors in vocational choice: interests, attitudes, aptitudes, social abilities
   b. Getting the job
2. Vocational problems on the job
   a. Success on the job: job satisfaction
   b. Promotion on the job: efficient study habits, effective thinking, intersocial problems

V. Factors of Supervision
Class: 6 hours
1. Employee selection
   a. Theory and art of interviewing
   b. Use of testing in industry

SOME SUGGESTED TEXTS AND REFERENCES

Davis, Keith, Human Relations at Work, 1966, McGraw-Hill Book Co., New York, 2nd. Ed.

Dunnette and Kirchner, Psychology Applied to Industry, 1965, Meredith Publishing Co.

Johnson, Donald, Psychology: A Problem-Solving Approach, 1961, Harper and Row.

Tuesing, Lyle, Psychology for Better Living, 1959, John Wiley & Sons, Inc., New York, N. Y.

INDUSTRIAL ORGANIZATION AND OPERATION

HOURS REQUIRED

Class - 3; Credit - 3.

DESCRIPTION

Preparation of engineering estimates and a detailed case study. An overall viewpoint of manufacturing, with specific emphasis on the areas of process planning, quality control, plant layout and safety.

MAJOR DIVISIONS

		Class Hours
I.	Comparative Cost Studies	3
II.	Preparation of Detailed Estimates	6
III.	Case Problem	6
IV.	Organization Charts and Functions	3
V.	Costs, Budgets and Financial Statements	5
VI.	Plant Layout and Material Handling	
VII.	Safety	
VIII.	Job Evaluation and Wage Administration	4
		33

I. Comparative Cost Studies
Class: 3 hours
1. Approximate methods

II. Preparation of Detailed Estimates
Class: 6 hours
1. Estimating labor requirements
2. Estimating material requirements
3. Allowances for contingencies
4. Estimating indirect labor requirements

III. Case Problem
Class: 6 hours
1. Case study
2. Student report

IV. Organization Charts and Functions
Class: 3 hours
1. Corporations and Organizations charts
2. Line and staff, span of control
3. Delegation, committees

V. Costs, Budgets, and Financial Statements
Class: 5 hours
1. Elements of costs (raw materials, labor, overhead)
2. Apportionment of costs
3. Budgets
4. Balance sheet
5. Income statement

VI. Plant Layout and Material Handling
Class: 4 hours
1. Product vs. process layout
2. How to improve

VII. Safety
Class: 2 hours
1. Costs, indices calculations
2. How to improve

VIII. Job Evaluation and Wage Administration
Class: 4 hours
1. Wage structure
2. Derived from job evaluation
3. Wage payment (day work, incentive)

SOME SUGGESTED TEXTS AND REFERENCES

Barish, N. N., Economic Analysis, 1962, McGraw-Hill Book Co., Inc., New York

Bethel, Atwater, etal; Industrial Organization and Management, 1962, McGraw-Hill Book Co., Inc., New York, N. Y.

DaGormo, E. P., Engineering Economy, 1960, The Macmillan Co., New York

Eilon, Samuel, Elements of Production Planning and Control, 1962, The Macmillan Co., New York

Folts, Franklin E., Introduction to Industrial Management, 1963, McGraw-Hill Book Co., Inc., New York

Grant, E. L. and Ireson, W. G., Principles of Engineering Economy, 1960, Ronald Press, New York

Keith, Lyman A., Introduction to Business Enterprise, 1962, McGraw-Hill Book Co., Inc., New York, N. Y.

Thueson, Engineering Economy, 1950, Prentice-Hall, Inc., Englewood Cliffs, New Jersey

Electronic News, 7 East 12th Street, New York, New York, 10003

Wall Street Journal, 711 West Monroe Street, Chicago, Illinois, 60606

ECONOMICS OF INDUSTRY

HOURS REQUIRED

Class - 3; Credit - 3.

DESCRIPTION

A study of the economic interdependency of the design, tooling, inspection and testing decisions and the means of quantifying such decisions. Fundamental economics applied on a micro scale; sources of direct, indirect, and fixed costs; cost accounting practices and their influence upon the engineering decisions; depreciation and taxation; generating alternatives based on principles of motion economy and work simplification; mathematics of finance, time dependent comparative cost studies.

MAJOR DIVISIONS

		Class Hours
I.	Fundamental Concepts of Economics	2
II.	Sources of Costs	10
III.	Allocation of Costs	5
IV.	Defining Alternatives	8
V.	Mathematics of Finance	3
VI.	Comparative Cost Studies	5
		33

I. Fundamental Concepts of Economics
Class: 2 hours
1. Selections from alternatives
2. Law of diminishing returns
3. Equivalence

II. Sources of Costs
Class: 10 hours
1. Direct labor
2. Employment costs
3. Supervision
4. Maintenance
5. Other indirect labor
6. Direct material costs
7. Purchasing costs
8. Fixed assets costs
9. Taxes

III. Allocation of Costs
Class: 5 hours
1. Accounting practice
2. Overhead distribution
3. Depreciation

IV. Defining Alternatives
Class: 8 hours
1. Sources of economic advantage
2. Principles of motion economy
3. Work simplification
4. Trade-off between sources of energy

V. Mathematics of Finance
Class: 3 hours

VI. Comparative Cost Studies
Class: 5 hours
1. Uniform annual cost studies
2. Present worth studies
3. Rate of return studies

SOME SUGGESTED TEXTS AND REFERENCES

Barish, N. N., Economic Analysis, 1962, McGraw-Hill Book Co., Inc., New York.

DaGormo, E. P., Engineering Economy, 1960, The Macmillan Co., New York.

Doyle, L. E., Tool Engineering, 1950, Prentice-Hall, Inc., Englewood Cliffs, New Jersey

Grant, E. L. and Ireson, W. G., Principles of Engineering Economy, 1960, Ronald Press, New York.

Lynn, Robert A., Basic Economic Principles, 1965, McGraw-Hill Book Co., Inc., New York

Samulson, Paul A., Economics: An Introductory Analysis, 1964, McGraw-Hill Book Co., New York, 6th Ed.

Thueson, Engineering Economy, 1950, Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

Electronic News - A Fairchild Publication, 7 East 12th St., New York, N. Y., 10003.

Wall Street Journal, 711 West Monroe Street, Chicago, Illinois, 60606.

AMERICAN GOVERNMENT

HOURS REQUIRED

Class - 3; Credit - 3.

DESCRIPTION

Nontechnical elective.

Functions of national, state and local governmental agencies.

MAJOR DIVISIONS

		Class Hours
I.	The Administrative Function	5
II.	Government Finance	5
III.	Judicial Administration and Law Enforcement	5
IV.	Government and Business	8
V.	Government and Labor	4
VI.	Agriculture and Natural Resources	
VII.	Safety, Health and Social Welfare	3
		33

I. The Administrative Function
Class: 5 hours
1. Nature and importance of administration in government.
2. Administrative organization and reorganization - national and state
3. Problems of administration
4. The civil service

II. Government Finance
Class: 5 hours
1. National revenues, expenditures, budgeting and debt administration
2. State and local finance

III. Judicial Administration and Law Enforcement
Class: 5 hours
1. Law enforcement agencies and their duties
2. Civil and criminal law procedures
3. Problems of legal procedures and administration of justice.

IV. Government and Business
Class: 8 hours
1. National regulation and promotion of foreign and domestic commerce, business and industry.
2. The states and business.

V. Government and Labor
Class: 4 hours
1. National labor legislation and regulations
2. The states and labor

VI. Agriculture and Natural Resources
Class: 3 hours
1. Government assistance to agriculture
2. Conservation of national resources.

VII. Safety, Health and Social Welfare
Class: 3 hours
1. Public health, morals
2. Social Security

SOME SUGGESTED TEXTS AND REFERENCES

DeGrazia, Alfred, The American Way of Government-National Edition, 1957, John Wiley & Sons, Inc., New York, N. Y.

DeGrazia, Alfred, The American Way of Government-National, State, and Local Edition, 1957, John Wiley & Sons, Inc., New York, N. Y.

Redford, Emmett S.; et al., Politics and Government in the United States, 1965, Harcourt, Brace & Co., New York, N. Y.

Office of Federal Register National Archives and Record Service, General Services Administration, United States Government Organization Manual, (annual), Washington, D. C., 20408

HISTORY, AMERICAN CIVILIZATION TO 1815

HOURS REQUIRED

Class - 3; Credit - 3.

DESCRIPTION

Nontechnical elective.

History of Western Civilization to 1815

Europe from the age of the great discoveries to the close of the Napoleonic Wars.

MAJOR DIVISIONS

		Class Hours
I.	Europe to Transition, (1300 - 1648)	18
II.	The Era of Enlightened Despotism, (1648 - 1789)	11
III.	The Era of the French Revolution, (1789 - 1815)	4
		33

I. Europe in Transition, (1300 - 1648)

Class: 18 hours

1. Introduction to modern times
2. The Renaissance
3. The Reformation in the Germanies
4. Calvinism and the Catholic Reformation
5. Spain and England in Reformation times
6. France in Reformation times
7. The Thirty Years' War

II. The Era of Enlightened Despotism, (1648 - 1789)

Class: 11 hours

1. The English Revolution in the Seventeenth Century
2. The Age of Louis XIV in France
3. Hapsburg Empire versus Hohensollern Prussia
4. The Rise of Russia
5. The Eighteenth Century

III. The Era of the French Revolution, (1789 - 1815)

Class: 4 hours

1. The French Revolution
2. Napoleon and the French Empire

SOME SUGGESTED TEXTS AND REFERENCES

Blake, Nelson Manfred, A History of American Life and Thought, 1963, McGraw-Hill Book Co., New York.

Morison, S. E.; Commager, Henry S., Growth of American Republic, Vol. 1, 1962, Oxford Press, 5th Ed.

Schevill, Ferdinand, A History of Europe from the Reformation to the Present Day, Harcourt, Brace & Co., New York

Preface To Options For Technical Electives

The six-quarter curriculum listed on page 10 designates a few courses as technical electives to be offered in the fifth and sixth quarters. Five options, along with possible courses for each of the options, were listed in a footnote to the curriculum.

More detailed information is presented on the following pages. For each option, the fifth and sixth quarters of the curriculum are adjusted to identify the specific courses required. General topical outlines of the special courses, as recommended for each of the options, are presented immediately following the adjusted curriculum of the appropriate option. The outlines for these special courses are not given in complete detail as was done for the required courses of the curriculum.

Certain courses, such as Computer Programming, are recommended for more than one of the options. In general, the courses for the technical elective should be selected from only one of the proposed options.

It is not the intent of this publication that all of the proposed technical elective courses should be available to the student. The courses and options are made available according to the objectives of a particular institution.

The material on the following pages is identified and indexed in the TABLE OF CONTENTS.

Power Option

Course	Hours Class	Laboratory	Contact	Credit
5th Quarter				
Electronics III (Advanced Electronics)	4	4	8	5
Physics III (Atomic)	3	2	5	4
Technical Report Writing	3	0	3	3
Advanced Power Circuits(1)	3	4	7	4
Economics of Industry	3	0	3	3
Seminar	0	0	1	0
	16	10	27	19
6th Quarter				
Rotating Machinery(1)	3	4	7	4
Power Distribution Systems(1)	3	4	7	4
Electrical Design(1)	3	4	7	4
Circuits IV (System Analysis)	1	4	5	3
Nontechnical Elective	3	0	3	3
Seminar	0	0	1	0
	13	16	30	18

(1) These are the technical electives for the Power Option. The topics for the courses may be selected from the general course outlines below and on the following pages.

ADVANCED POWER CIRCUITS

1. Representation of Power Systems
   a. Equivalent circuits - transfer impedance
   b. Per cent and per cent quantities
   c. One line diagram equivalent circuits
      (1) 2-winding and 3-winding transformers
      (2) Transmission lines
      (3) Synchronous machines
      (4) Induction machines
2. Symmetrical Components
   a. N-phase symmetrical components
   b. Three-phase symmetrical components
   c. Instantaneous power
   d. Average power
3. Positive, Negative, and Zero-sequence Impedances of Network Components (Sequence Networks)
   a. 2-winding and 3-winding transformers
   b. Phase shift in wye-delta transformer banks
   c. Transmission lines
   d. Synchronous machines
   e. Induction machines
4. Unsymmetrical Short-circuits On Unloaded Generators
   a. Reference for voltage
   b. Fundamental sequence relations
   c. Short-circuit analysis
      (1) Line-to-ground fault
      (2) Line-to-line fault
      (3) Double line-to-ground fault
5. Unsymmetrical Faults on Normally Balanced Power Systems
   a. Fundamental sequence network relations
   b. Short-circuit of zero impedance

   - c. Faults through impedance
   - d. Open conductors
   - e. Network analyzer in fault studies
6. Unsymmetrical Power Systems
   - a. Impedance to positive, negative, and zero-sequence currents
   - b. Sequence self and mutual inductance
   - c. Analysis of unsymmetrical loads and series circuits
   - d. Faults consideration of unsymmetrical wye-connection loads
   - e. Transformer banks of dissimilar units
   - f. Short-circuits on a system containing unsymmetrical circuits
7. Matrix Algebra in Symmetrical Component Analysis
   - a. Matrix formulation of symmetrical components
   - b. Unbalanced loads
   - c. Faults on unloaded generators

ROTATING MACHINERY

1. D-C Machines
   - a. Dynamo principles
   - b. Winding of D-C Machines
   - c. Steady-state study of D-C machines
     - (1) Magnetization curve-voltage build-up
     - (2) Armature reaction, compensating windings
     - (3) Reactance voltages, interpoles
     - (4) Dynamo voltage characteristics
     - (5) Generator operation and motor speed-torque characteristics
   - d. Generalized equations for D-C machines
     - (1) D & Q axis concept--how to visualize windup and write equations--emphasis on limitations
     - (2) Application of linearized equations to steady-state problems already covered
     - (3) Application to transients, use of operational calculus as applied to machine problems

2. A-C Machines
   - a. Introduction and description
   - b. The windings of A-C machines from mmt and induced voltage standpoint
   - c. The polyphase induction motor
     - (1) Development and use of equivalent circuit
     - (2) Methods of testing
   - d. The synchronous machine
     - (1) Equivalent circuit and vector diagrams
     - (2) Motor and generator operation
     - (3) Synchronous machines and power factor correction
   - e. Application of D & Q axis theory to A-C machines

POWER DISTRIBUTION SYSTEMS

1. Line Parameters
   - a. Resistance, capacitance, and inductance
   - b. Transpositions
   - c. Parallel lines
2. Transmission Line Theory
   - a. Derivation of equations
   - b. Vector significance of equations
   - c. Equivalent Pi and Tee
   - d. Nominal Pi and Tee
3. Circle Diagram
   - a. Derivation of equation of circle
   - b. Receiver and sending circles
   - c. Loss lines
4. Symmetrical Components
   - a. Basic theory
   - b. Fault calculations by equivalent circuits
   - c. Network impedances and reduction
   - d. Determination of currents and voltages at various points
   - e. Demonstration of network analyzer

5. Mechanical and Cable Characteristics
   - a. Sag and stress
   - b. Sequence values
   - c. Charging KVA
   - d. Effects on system operation

6. Zero Sequence Impedance of Transmission Lines
   a. Parallel lines with and without ground-wires
   b. Multi-winding transformer sequence impedance

7. Measurement of Symmetrical Voltages, Currents, and Power
   a. Simultaneous fault calculations
   b. System stability (steady-state)
   c. Transmission line surges
   d. One-line diagrams of systems

ELECTRICAL DESIGN

1. Lighting Layout
   a. Analyzing the lighting problem
   b. Selection of light level
   c. Lighting quality
   d. Light control
   e. Selection and efficiency of light source
   f. Lighting system, distribution and equipment
   g. Lighting calculations and layout

2. Power Circuit Layout
   a. Types of loads
   b. Selection of motors
   c. Selection of controls
   d. Layout of circuits

Computer Option

Course	Hours			
	Class	Laboratory	Contact	Credit
5th Quarter				
Electronics III (Advanced Electronics)	4	4	8	5
Physics III (Atomic)	3	2	5	4
Technical Report Writing	3	0	3	3
Computer Logic(1)	3	4	7	4
Computer Programming(1)	3	open	3	3
Seminar	0	0	1	0
	16	10	27	19
6th Quarter				
Analog Computers(1)	3	4	7	4
Measuring Principles (Mechanical and Electrical) (1)	3	4	7	4
Economics of Industry	3	0	3	3
Circuits IV (System Analysis)	1	4	5	3
Nontechnical Elective	3	0	3	3
Seminar	0	0	1	0
	13	12	26	17

(1)These are the technical electives for the Computer Option. The topics for the courses may be selected from the general course outlines below and on the following pages.

COMPUTER LOGIC

1. Number Systems (conversions)
    a. Base 10
    b. Base 2
    c. Base n
2. Number Representation
    a. Sign, magnitude
    b. Radix compliments
    c. Dimenishing radix compliments
3. Logic Components
    a. And, or, not
    b. Nor, and, nand
    c. Flip-flop
4. Boolean Algebra
    a. Theorems
    b. Reduction of logic functions
5. Computer Organization
6. Arithmetic Methods

COMPUTER PROGRAMMING

1. Computer Applications
   a. Efficiency
   b. Application requirements
2. Organization of Computer Processing System
   a. Component logic
   b. Instruction format and data flow (computer units)
   c. Computer system
3. Instruction: Card System
   a. Format control codes
   b. Card system (input-out)
4. Programming Languages
   a. Scatter
   b. Fortran
   c. Solving basic algebra - trigonometric problems
5. Loops and Indexing
   a. Steps in programming
   b. Index register
6. Subroutines
   a. Open subroutine
   b. Closed subroutine
7. Assembly Programs and Compiles
   a. Concepts
   b. Introduction to specific programming
8. Magnetic Tape
   a. Organization
   b. Instruction
9. Monitors
   a. Concepts
   b. Application areas
10. Advancing Programming Systems and Techniques
    a. Solving differential calculus problems
    b. Solving integral calculus problems
    c. Numerical solutions of linear simultaneous equations

ANALOG COMPUTERS

1. Introduction to computers
   a. Comparison of analog and digital computers
   b. Historical development
   c. Classification of analog equipment
   d. Major analog components needed
2. Computer Components
   a. Potentiometers
   b. Operational amplifier
      (1) As sign changer
      (2) As summing amplifier
      (3) As summing integrator
   c. Function multipliers
   d. Function generators
   e. Output devices--recorders, plotters
   f. Computer design differences
3. Signal Flow Graphs
   a. Flow graph algebra
   b. Application to computer programming
4. Analog Computer Programming
   a. Linear algebraic equations and computer stability
   b. Machine variables and amplitude scaling
   c. Time scaling
   d. Implicit function generation
5. Multiplying and Resolving Servo Units
   a. Multiplication
   b. Division
   c. Square and cube root
   d. Rectangular and polar resolution
   e. Function generation
6. Miscellaneous Computer Techniques
   a. Use of diodes and function relays
   b. Generalized integration
   c. Approximate differentiation
   d. Use of diode function generation
   e. Special computer set-up and applications
7. Checking Computer Results
   a. Static check
   b. Partial system check
   c. Controlled solution check
   d. Other checks

MEASURING PRINCIPLES (MECHANICAL AND ELECTRICAL)

Refer to Instrumentation Option for course outline.

High Frequency Communication And Transmission Option

Course	Hours			
	Class	Laboratory	Contact	Credit
5th Quarter				
Electronics III (Advanced Electronics)	4	4	8	5
Physics III (Atomic)	3	2	5	4
Technical Report Writing	3	0	3	3
Fields and Waves(1)	3	open	3	4
Transmission Lines(1)	3	4	7	4
Seminar	0	0	1	0
	16	10	27	19
6th Quarter				
Microwave Fundamentals(1)	3	4	7	4
UHF Communication and Reception(1) or, Antennas(1)	3	4	7	4
Economics of Industry	3	0	3	3
System Analysis	1	4	5	3
Nontechnical Elective	3	0	3	3
Seminar	0	0	1	0
	13	12	26	17

(1)These are the technical electives for High Frequency Communication and Transmission Option. The topics for the courses may be selected from the general course outlines below and on the following pages.

FIELDS AND WAVES

1. Maxwell's Equations and Boundary Conditions
2. Electromagnetic Waves
   a. Wave equations
   b. Uniform plane waves
3. Reflection and Refraction of Plane Waves
   a. Normal and oblique incidence on conductors and dielectrics
   b. Transmission line analogy for multilayer problems
4. Power Flow - Poynting Vector
5. Boundary Value Problems - Waveguides
   a. Parallel plane, rectangular, and circular waveguides
   b. Modes, cut-off, phase and group velocities
   c. Attenuation, impedance
   d. Transmission line analogy
   e. Discussion of boundry value problem techniques
   f. Resonant cavities, Q
6. Radiation and Antennas
   a. Vector potential, gauge
   b. Fields of electric dipole
   c. Kirchhoff integration
   d. Fields of monopole and dipole
   e. Radiation resistance, radiation pattern

TRANSMISSION LINES

1. Fundamental Definitions
2. Hyperbolic Trigonometry
3. Distribution Constants
4. Transmission Line Equation
5. Infinite Line
6. General Transmission Line Consideration
7. High Frequency Lines
8. Dissipation Lines
9. Impedance Diagrams
10. Low-Loss Lines

MICROWAVE FUNDAMENTALS

1. Coaxial System
2. Detection of Microwave Power
3. Microwave Sources
4. Operation of the Klystron Oscillator
5. Measurement of Frequency and Wavelength in Waveguide
6. Measurement of Power at Microwave Frequencies
7. Impedance Measurements in Waveguides
8. Basic Antenna Patterns
9. Absorption and Reflection of Centimeter Waves

UHF COMMUNICATION AND RECEPTION

1. UHF Generators
2. Vector Analysis
3. Vector Notation (Steady Electric and Magnetic Fields)
4. Maxwell's Equations
5. Wave Equation
6. Rectangular Waveguides
7. Circular guides
8. Antennas

ANTENNAS

1. Electromagnetic Waves
2. Transmission Lines
3. Antenna Parameters
4. Basic Radiators and Feed Methods
5. Arrays
6. Reflectors and Lenses
7. Antennas With Special Properties
8. Antenna Measurements

Instrumentation Option

Course	Hours Class	Hours Laboratory	Hours Contact	Hours Credit
5th Quarter				
Electronics III (Advanced Electronics)	4	4	8	4
Physics III (Atomic)	3	2	5	4
Technical Report Writing	3	0	3	3
Measuring Principles (Mechanical and Electrical)(1)	3	4	7	4
Computer Programming(1)	3	open	3	4
Seminar	0	0	1	0
	16	12	27	19
6th Quarter				
Standards and Calibration(1)	3	4	7	4
Control Principles and Telemetry(1)	3	4	7	4
Economics of Industry	3	0	3	3
System Analysis	1	4	5	3
Nontechnical Elective	3	0	3	3
Seminar	0	0	1	0
	13	12	26	17

(1) These are the technical electives for the Instrumentation Option. The topics for the courses may be selected from the general course outlines below and on the following pages.

MEASURING PRINCIPLES (MECHANICAL AND ELECTRICAL)

1. Pressure Gauges
2. Liquid and Gas Flow Measurements
    a. Temperature
    b. Pressure
    c. Rate of flow
3. Temperature and Humidity Measurements
4. Viscosity Measurements
5. Transducers
    a. Level
    b. Temperature
    c. Radiation
6. Electrical Devices
    a. Flow devices
    b. Potentiometric
    c. Humidity - measuring
7. Indicating, Recording, and Registering Equipment
8. Analytical Instruments

CONTROL PRINCIPLES AND TELEMETRY

1. Process characteristics
    a. Static conditions
    b. Kinetic conditions
2. Systems, Components and Responses
3. Control Systems
    a. Hydraulic - pneumatic
    b. Electronic
4. Solid State Amplifiers
5. Solid State Switching
    a. Silicon control rectifiers
    b. High power switching
6. Magnetic Amplifiers and Saturable Core Reactors

STANDARDS AND CALIBRATION

1. Recording and Storage of Data
2. Laboratory Standards, E, I, R, P, F
    a. Theory
    b. Calibration
3. Working Laboratory Standards
    a. Calibration
    b. Utilization
4. Calibration and Adjustment
    a. Mechanical instruments
    b. Electrical instruments

COMPUTER PROGRAMMING

Refer to Computer Option for course outline.

Industrial Control Systems Option

Course	Hours			
	Class	Laboratory	Contact	Credit
5th Quarter				
Electronics III (Advanced Electronics)	4	4	8	5
Physics III	3	2	5	4
Technical Report Writing	3	0	3	3
Industrial Control Circuits and Components(1)	3	4	7	4
Computer Programming(1)	3	open	3	4
Seminar	0	0	1	0
	16	14	27	20
6th Quarter				
Servomechanism(1)	3	4	7	4
Measuring Principles (Mechanical(1) and Electrical)	3	4	7	4
Economics of Industry	3	0	3	3
System Analysis	1	4	5	3
Nontechnical Elective	3	0	3	3
Seminar	0	0	1	0
	13	12	26	17

(1) These are the technical electives for Industrial Control Systems Option. The topics for these courses may be selected from the general course outlines below and on the following pages.

INDUSTRIAL CONTROL CIRCUITS AND COMPONENTS

1. Component Analysis and Characteristics
   a. Relays, switches and contactors
   b. Series impedance transformers
   c. Peaking transformers
   d. Semiconductor, high current devices
   e. Industrial tubes
   f. Transducers
2. Control Circuits and Characteristics
   a. Timers, triggering and counting circuits
   b. Photoelectric control circuits
   c. High power oscillators
   d. Magnetic amplifiers
   e. Phase shift circuits

SERVOMECHANISM

1. Introduction to Feedback Control Systems
2. Equations of Linear Systems
3. Mathematics of Control Systems
4. Components of Feedback Control Systems
5. Transient Response of Feedback Control Systems
6. Steady State Errors
7. Stability of Feedback Control Systems
8. Frequency Response Methods
9. The Nyquist Criterion
10. The Root Locus Technique
11. Compensation of Feedback Control Systems

COMPUTER PROGRAMMING

Refer to Computer Option for course outline.

MEASURING PRINCIPLES (MECHANICAL AND ELECTRICAL)

Refer to Computer Option for course outline.

Appendix Contents

Laboratory Facilities And Equipment

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APPENDIX B: Laboratory Furniture for Required Courses
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APPENDIX C: Recommended Equipment List for Required Courses
  A. Instruments
    1. Circuits Laboratory
    2. Electronics Laboratory
  B. Related Equipment and Supplies
    1. Laboratory Furniture
    2. Small Parts
    3. Components
  C. Summary of Total Equipment Cost for Required Laboratories
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  D. Master Reference Catalogues

APPENDIX D: Physical Arrangement of Laboratory Work Stations
  A. Acceptable Laboratory Work Area Organization
    1. Objectives of the Acceptable Laboratory Work Area Organization
    2. Figures Showing Acceptable Laboratory Work Area Arrangement
  B. Laboratory Utilization

APPENDIX A

Laboratory Space Requirements

LABORATORY FOR REQUIRED CIRCUITS COURSES

A

LABORATORY FOR REQUIRED ELECTRONICS COURSES

B

OPEN LABORATORY
(Staff and Student)

1. Individual Experimentation
2. Fabrication
3. Developmental

C

LABORATORY FOR TECHNICAL ELECTIVE COURSES

D

MAINTENANCE
AND
SUPPLY

E

A. Laboratory to meet requirements for the required circuits courses offered within the curriculum.

B. Equipped to meet requirements for the required electronics courses offered within the curriculum.

C. Staff and/or student supervised open laboratory.

D. Speciality area, or areas, for teaching technical specialities: UHF, microwave, servomechanisms, etc.

E. Contains equipment and personnel capable of maintaining and servicing electronics equipment, not open to students.

APPENDIX B

Laboratory Furniture For Required Courses

A. Worktables - Benches
  1. Size of bench top:
    a. 1 3/4" x 24" x 48" to 1 3/4" x 36" x 84"
    b. 1 3/4" x 36" x 72" is recommended size
  2. Bench top material:
    a. Steel
    b. Prestwood-covered steel
    c. Laminated maple (this is recommended because of the necessity of a non-conducting bench top)
  3. Height of bench above floor:
    a. 29" to 36" plus the bench top
    b. 36" plus the bench top is recommended
  4. Table - bench structure (modular units)
    a. Base units:
      1. Drawer pedestal
      2. Cabinet pedestal
      3. Panel leg
      4. Locker base
      5. Bench: cabinets
      6. Continuous benches; cabinet type
    b. Accessories
      1. Individual drawers
      2. Enclosed drawers
      3. Top shelf
      4. Wire mold
      5. Electrical panels
  5. Chairs
    a. For work stations
      1. Standard stool size, 18-33 inches, adjustable over a 4-inch height
      2. 24-inch stool size recommended
    b. For calculating tables
      1. Side chair
      2. Stacking side chair. This is recommended

  6. Calculating tables
    a. Standard table sizes (burn resistant tops)
      1. Individual (with drawer) 34" x 26" to 46" x 31"
      2. Conference, 45" x 30" to 96" x 42"
    b. Individual size recommended for modular development

  7. Shelving and cabinets (standard size 36" wide 87" high)
    a. All small drawers (component storage)
    b. Small drawers and larger storage compartments
    c. Shelving closed on three sides
    d. Shelving open all around
    e. Cabinet shelving with hinged locking door
    f. Cabinet shelving with sliding locking door
    g. Slotted angle, do-it-yourself design

APPENDIX C

Recommended Equipment List

A. Instruments

1. Circuits Laboratory:

NUMBER	ITEM	COST			
		MINIMUM		MAXIMUM	
		Unit	Sub-Total	Unit	Sub-Total
10	Oscilloscope (Dual Trace), with Scope Camera Mounting Bezel	$ 850	$ 8,500	$1,800	$18,000
10	VTVM	250	2,500	525	5,250
10	Square Wave Generator	350	3,500	500	5,000
20	Power Supplies (Low Voltage)	175	3,500	325	6,500
10	Sine Wave Generator	225	2,250	400	4,000
5	Volt-Ohm/Milliampere Meter	55	275	100	500
20	Watt-Meters (Varying Ranges)	50	1,000	150	3,000
5	Oscilloscope Cameras (Film Pack type)	250	1,250	450	2,250
	TOTAL	$2,205	$22,775	$4,250	$44,500

2. Electronics Laboratory:

NUMBER	ITEM	COST			
		MINIMUM		MAXIMUM	
		Unit	Sub-Total	Unit	Sub-Total
Same Items as Circuits Laboratory		$ 2,205	$22,775	$ 4,250	$ 44,500
10	R-F Signal Generator	900	9,000	1,350	13,500
1	Curve Tracer	1,500	1,500	2,200	2,200
2	Wave Analyzer	2,000	4,000	3,000	6,000
1	X-Y Recorder	1,600	1,600	3,000	3,000
1	Tube Tester	400	400	600	600
5	Sweep Generator	2,000	10,000	3,000	15,000
1	Digital Potentiometric Voltmeter	1,500	1,500	4,000	4,000
1	Digital Frequency Meter	2,000	2,000	4,000	4,000
1	Function Generator	1,600	1,600	1,600	1,600
1	Programable Pulse Generator	1,100	1,100	1,800	1,800
1	Communications Receiver KHz to 30 + MHz	1,000	1,000	1,600	1,600
2	R-L-C Bridges	400	800	700	1,400
20	Assortment D-C Meters, (µa-ma)	15	300	25	500
10	Power Supplies (High Voltage)	250	2,500	400	4,000
	TOTAL	$18,470	$60,075	$31,525	$103,700
Total cost, both laboratories		$20,675	$82,850	$35,775	$148,200

Note: Specify type of connectors desired when ordering equipment. Test leads and probes are not always included with instruments.

B. Related Equipment and Supplies (In Sufficient Quantity to Satisfy Laboratory Needs of Ten Squads)

1. Laboratory Furniture

	Cost MINIMUM	Cost MAXIMUM
a. Worktables	$2,000	$8,000
b. Stools	140	300
	$2,140	$8,300

2. Small Parts

	MINIMUM	MAXIMUM
a. Leads With Connectors, cost: 1 to 2 dollars	$ 300	$ 600
b. Special Connectors, cost: 1 to 5 dollars	50	100
c. Tubes, cost: 1 to 3 dollars	100	500
d. Transistors, cost: .50 to 5 dollars	50	500
e. Miscellaneous Semiconductor Devices	200	500
TOTAL	$ 700	$2,200

3. Components

	MINIMUM	MAXIMUM
a. Resistor Substitution Boxes, cost: 10 to 15 dollars	$ 600	$ 900
b. Capacitor Substitution Boxes cost: 10 to 15 dollars	600	900
c. Assortment of Inductors cost: 3 to 5 dollars	200	300
TOTAL	$1,400	$2,100

C. Summary of Total Equipment Cost for Required Laboratories

1. Circuits Laboratory:

	Cost MINIMUM	Cost MAXIMUM
a. Instruments	$22,775	$44,500
b. Small Parts	700	2,200
c. Components	1,400	2,100
d. Furniture	2,140	8,300
TOTAL	$27,015	$57,100

2. Electronics Laboratory:

a. Instruments	$60,075	$103,700
b. Small Parts	700	2,200
c. Components	1,400	2,100
d. Furniture	2,140	8,300
	$64,315	$116,300

3. Total Cost of Both Laboratories	$91,330	$173,400

4. Recommended Costs:

The summary of costs is indicative of the wide-range and sophistication of the equipment involved. When considering a general rule for purchasing this equipment, the total cost of the circuits laboratory should be approximately $40,000; the electronics laboratory $80,000. These costs can vary in accordance with those indicated above and the respective needs of a specific situation.

D. Master Reference Catalogues

1. Electronic Buyer's Guide, 330 W. 42nd Street, New York, N. Y. 10036
2. Electronic Engineers Master Catalog and Purchasing Guide of the Electronics Industry, United Technical Publications, Inc., 645 Stewart Avenue, Garden City, N. Y. 11530
3. Radio-Electronic Master, United Technical Publications, Inc., 645 Stewart Avenue, Garden City, N. Y. 11530

APPENDIX D

Physical Arrangement Of Laboratory Work Stations

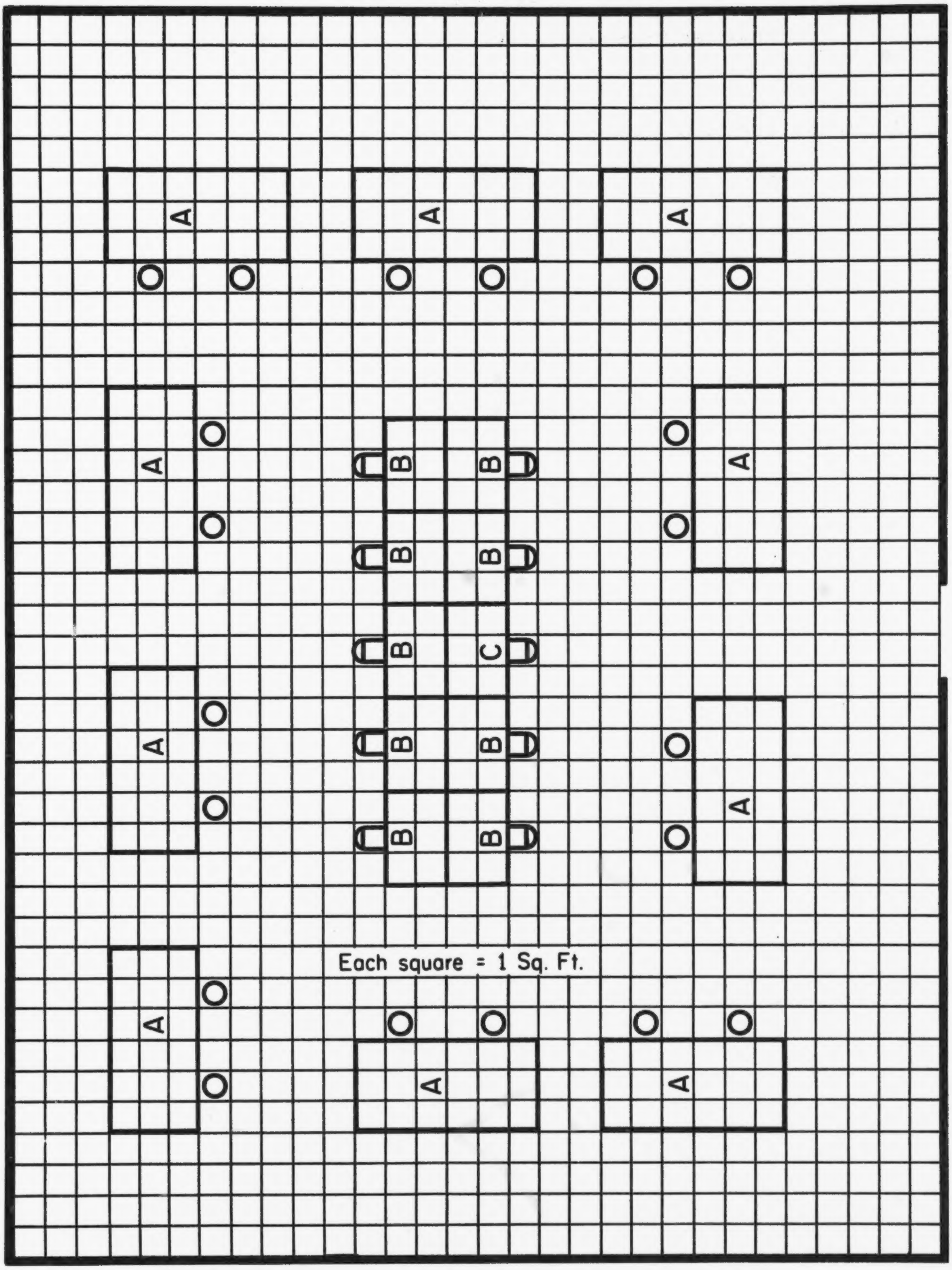
A. Acceptable Laboratory Work Area Organization:

1. Objectives of the acceptable laboratory work area
    a. Instructor has an overview of all laboratory stations from a central location
    b. Chalk board available for each work station
    c. Calculation table for each work station
2. See figures D-1 to D-4 showing acceptable laboratory work area arrangement

B. Laboratory Utilization

Many laboratory arrangements are possible. Some laboratory arrangements are better than others depending upon the objectives of the laboratory in question. The Figs. D-1 to D-4 represent the recommended laboratory layout for conducting the required Circuits and Electronics laboratory portions of the two-year technology program.

The laboratory layout shown in Figs. D-1 to D-4 represents only the work area where the students will be located. No consideration is given, in the floor plan, to storage of components, equipment and miscellaneous items.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Each square = 1 Sq. Ft.
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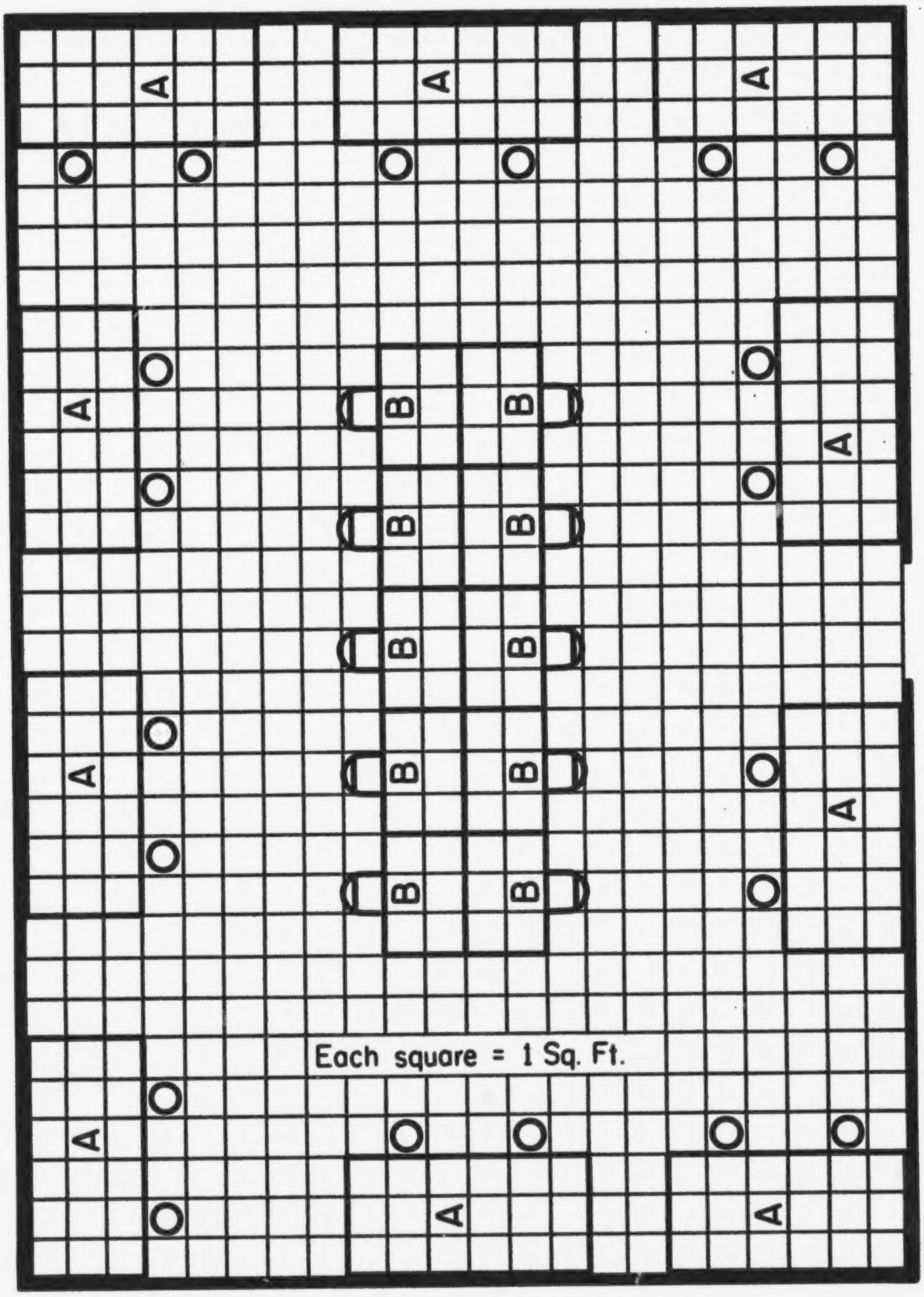
Fig. D-1 A floor plan of laboratory work stations and calculating tables. Instructor can observe all work stations (A) from central location (C). Allows 56 sq. ft. per station. Space around outside is for storage, chalkboards, special equipment, etc.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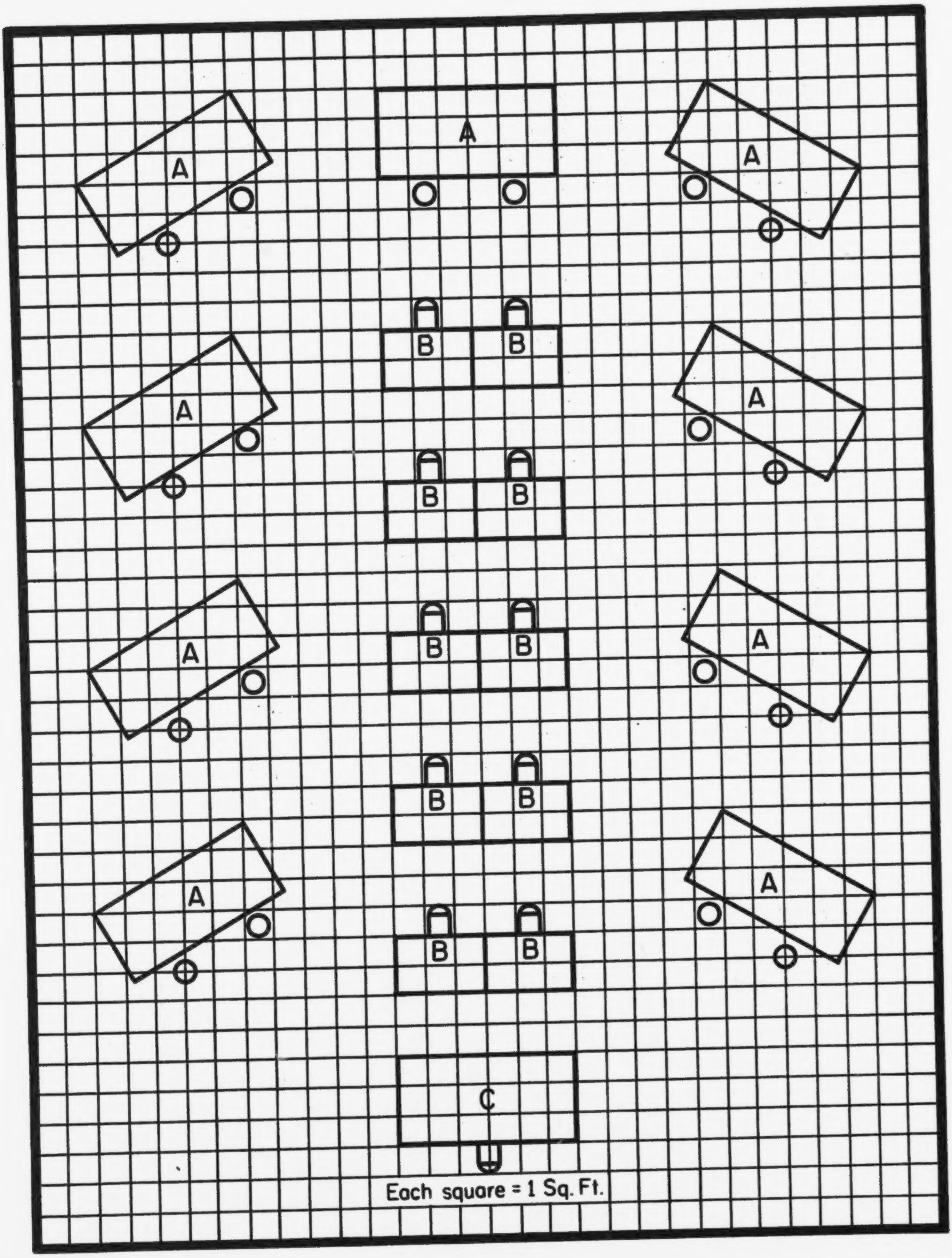
Each square = 1 Sq. Ft.

Fig. D-2 Same as Fig. D-1 with space around the outside of work stations omitted.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C
Each square = 1 Sq. Ft.

Fig. D-3 A floor plan with work stations placed at an angle to allow convenient monitoring, by the instructor, from one end of the room.

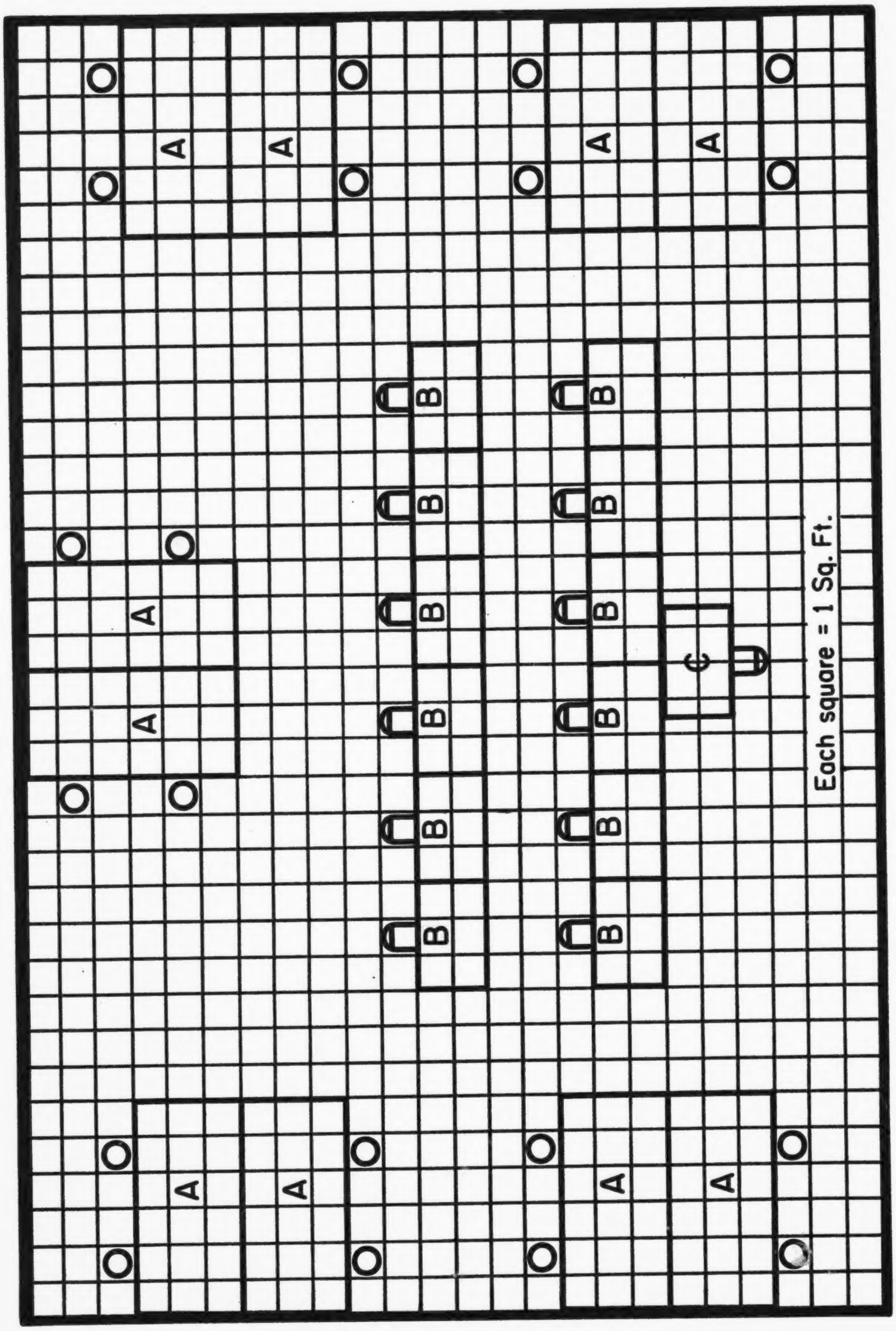
A
B
C
Each square = 1 Sq. Ft.

Fig. D-4 An alternate floor plan with work stations located for convenience in running power lines to work benches. Inconvenience to the instructor is a disadvantage.